building bulletin

MINISTRY OF EDUCATION

AUGUST, 1960

17

DEVELOPMENT PROJECTS:
SECONDARY SCHOOL, ARNOLD

HMSO 8s. 6d. NET

BUILDING BULLETIN No. 17

August 1960
(Reprinted 1966)

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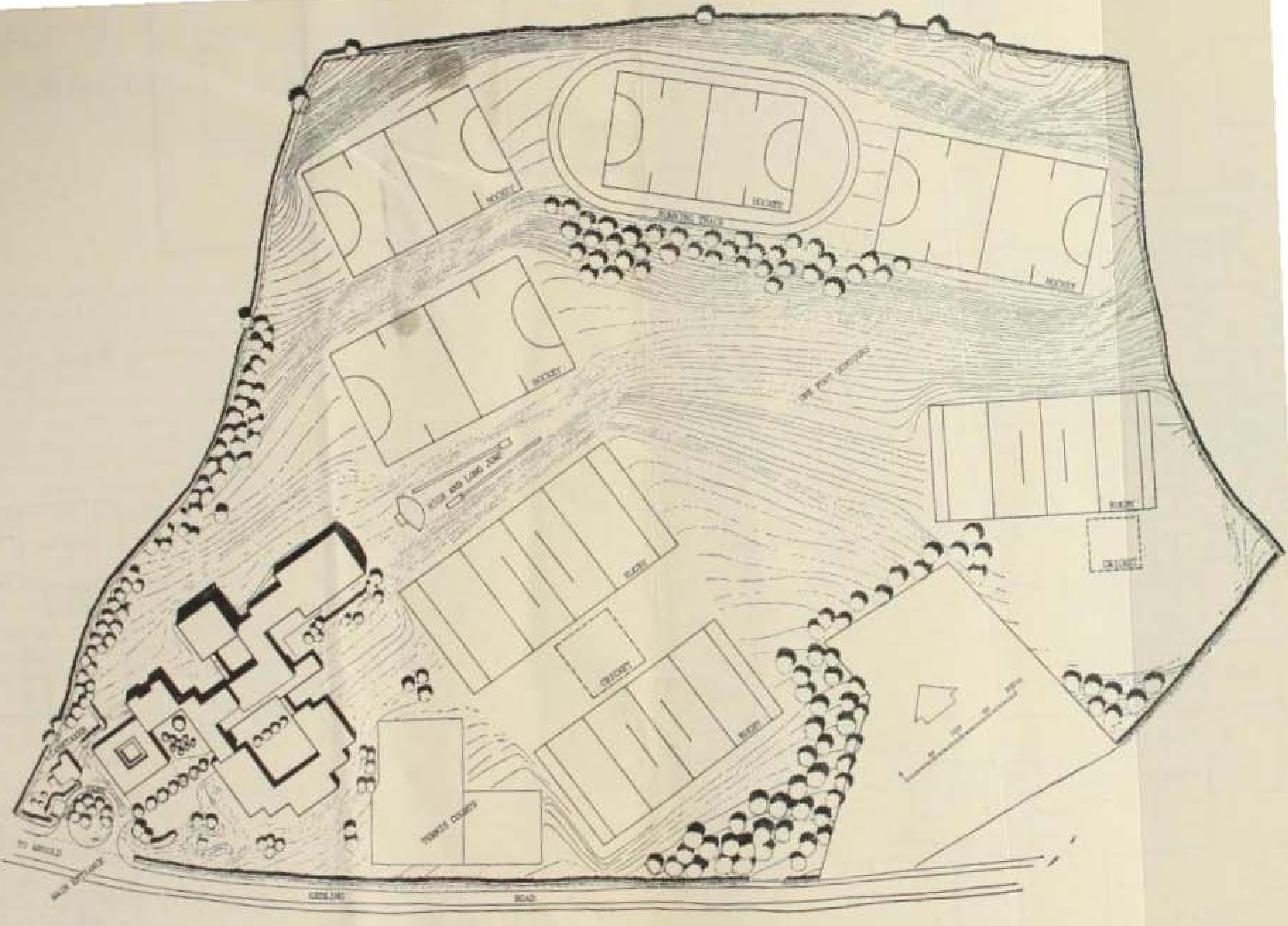
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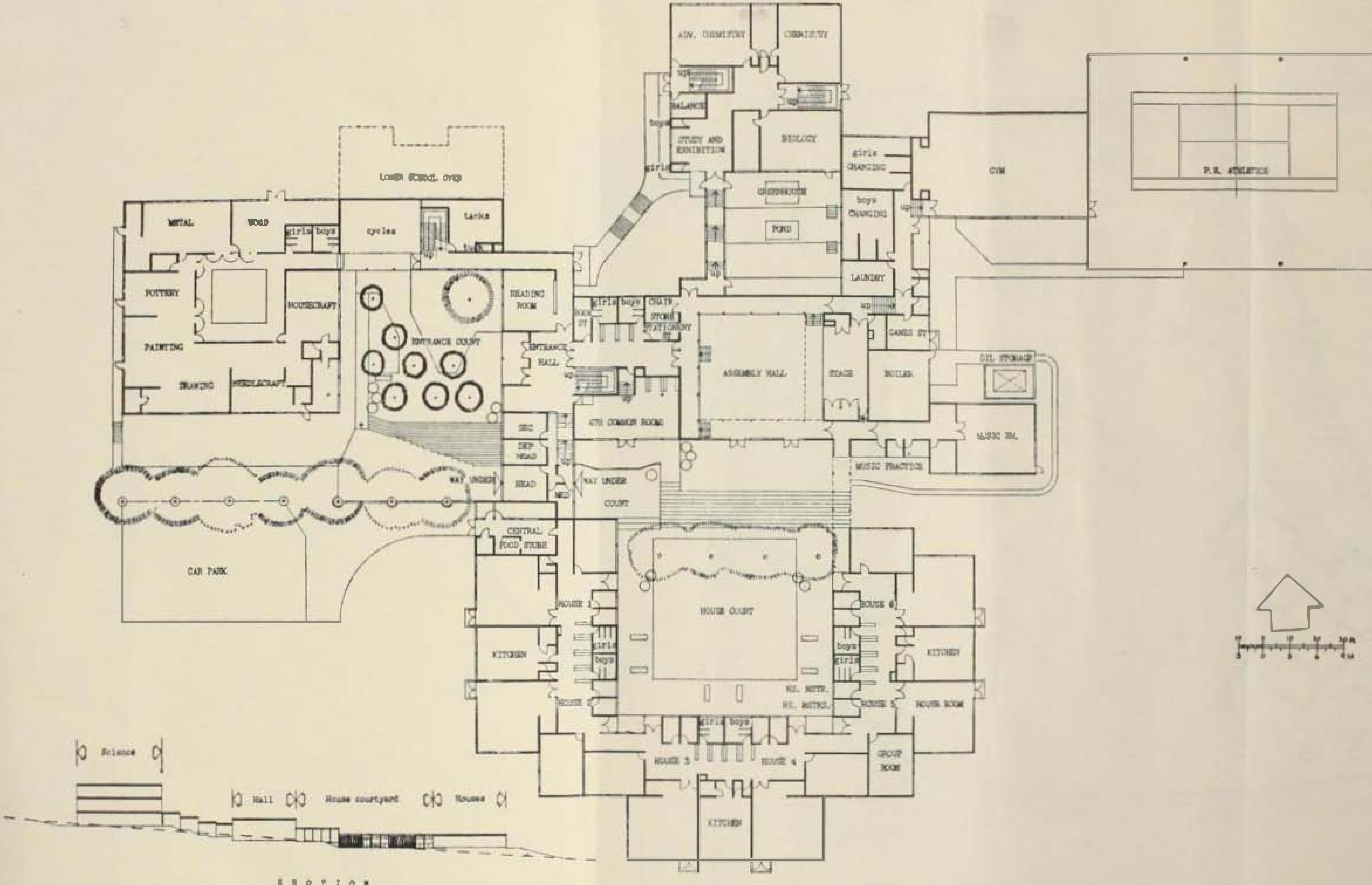
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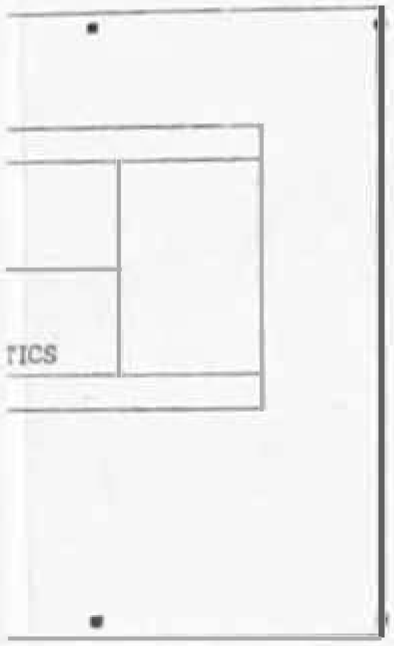

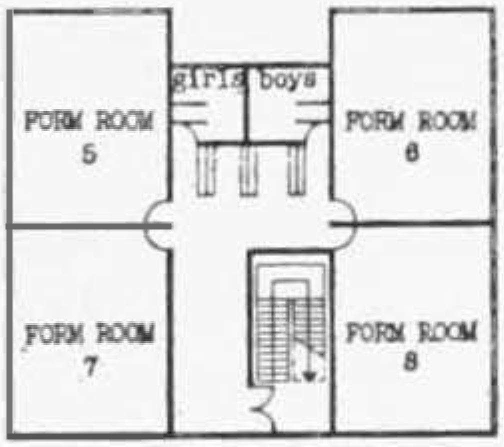

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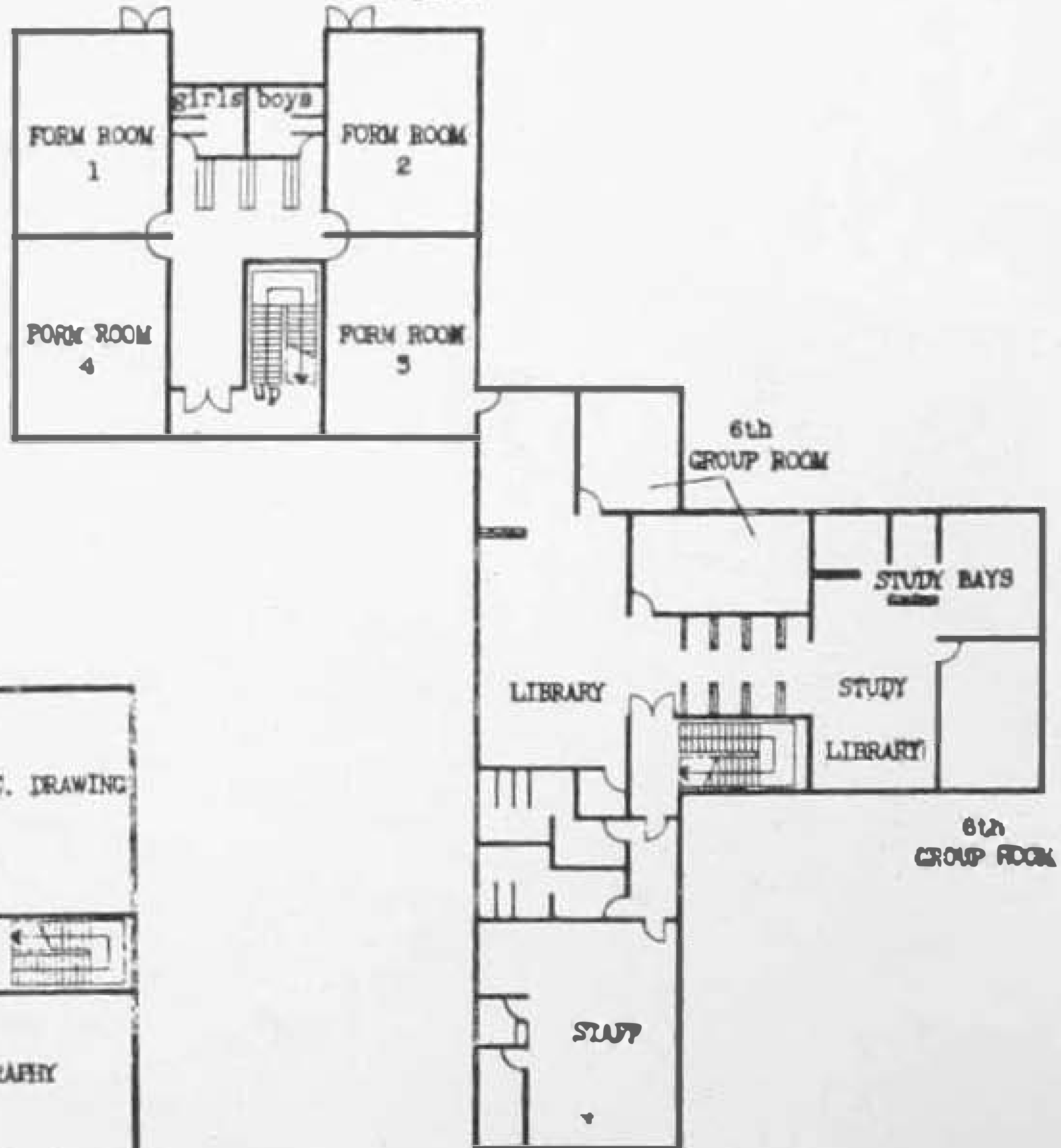

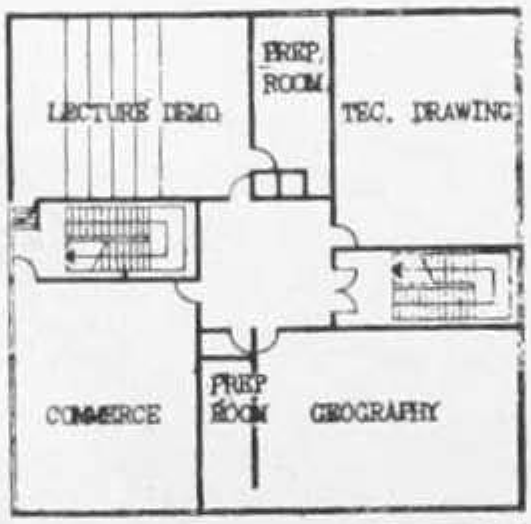

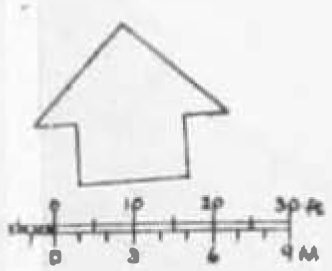

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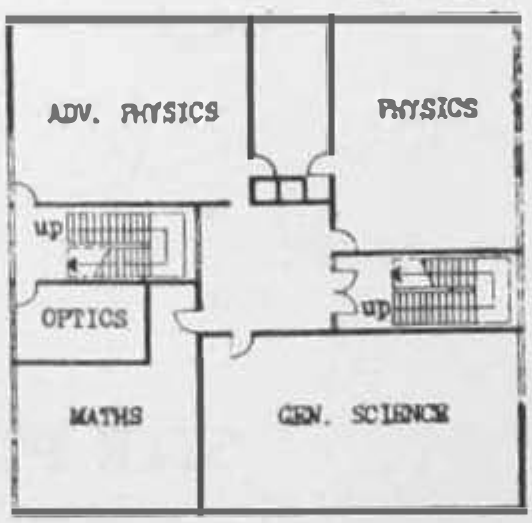


DEVELOPMENT PROJECTS: SECONDARY SCHOOL, ARNOLD

INTRODUCTION

1. This BULLETIN describes a secondary school at Arnold, Nottinghamshire, designed by the Development Group of the Architects and Building Branch of the Ministry of Education in collaboration with the Local Education Authority. It was the sixth secondary school undertaken by the Group for the purposes of research into educational and technical requirements, and it embodies some unusual features both in the plan and in the new system of construction developed.

2. The educational objective was to design a building suitable for selected pupils wishing to study for various qualifications leading to employment in industry and the professions. Such pupils would normally attend a grammar school. It has been observed, however, that with the passage of years grammar school methods have changed, the forms of organisation have been modified and new courses have been introduced so that older buildings often lack the variety of accommodation now required. In particular, scientific and technological studies have expanded. They require laboratories and workshops which are more highly specialised than the class or lecture rooms suitable for teaching the traditional subjects such as the classics or modern languages. In order to study these new requirements and to learn how they could be fitted into a school building side by side with more conventional accommodation, members of the Development Group, including educationists and architects, visited many grammar schools. They observed current educational practice and discussed ideas and objectives with the teachers. Part I of this BULLETIN describes how their findings were ultimately embodied in the plan of Arnold School.

3. Part II describes the structure of the school. The opportunity was taken in this project to design, in collaboration with the contractors, a new system of pre-cast concrete components which would be a useful addition to the choice of systems available to local education authorities in tackling their building programmes.

4. Part III is concerned with cost and provides an example of the use of the techniques propounded in BUILDING BULLETIN No. 4 (Second Edition).* The special objective given to the development team (which included the nominated contractor) was to design a structural system for a cost 20 per cent lower than that of similar systems.

*Ministry of Education Building Bulletin No. 4—Cost Study (H.M.S.O. 8s. 6d.)

I. PLANNING

GENERAL INVESTIGATION OF EDUCATIONAL REQUIREMENTS

5. Two interesting features of current educational development, important in themselves and in their particular effect on school buildings, were noted during visits to grammar schools. The first was that the teaching group, normally thirty in secondary schools, was often twenty or even fewer. This was true, not only of the sixth forms where it was understood that it has long been the practice to teach in small groups, but in other parts of the school as well. Instances were found where fourth and fifth year pupils were organised in teaching "sets" of twenty to twenty-five. The second was that more than half the pupils admitted to the schools were remaining for a full seven year course. It was said that this proportion was increasing.

6. It was evident that headmasters were anxious to develop the individual aptitudes of pupils both by permitting a free choice of certain subjects and by offering general and specialised courses in others. Smaller teaching groups seemed to result from the wider range of courses thus made available. For example, a year of 90 pupils formerly taught in three forms of thirty was sometimes set in as many as five teaching groups each following a distinctive course.

7. Not only was the number of sixth form pupils steadily increasing, but the wide variety of subjects which they chose made it necessary for them to be taught in many groups of varying sizes. In one school visited, the sixth form teaching groups ranged in size from a lower sixth science of 20 pupils to a single third year sixth scholarship arts student working with his tutor.

8. These smaller groups were organised within normal staffing ratios. Some teachers said they enjoyed taking the small groups, even if it meant that their personal time-tables were heavier, because they got to know their pupils so much better and response was more spontaneous and fruitful. Others said that pupils' private study was more concentrated and their work better informed and well-balanced because of the individual attention they received. To counter-balance the extra demands thus made on the teaching staff it was noticed that many sixth form pupils worked on their own for as much as half the school day; it was by no means unusual to find time-table periods for private study allocated in fifth and even, occasionally, in fourth forms.

9. The second trend referred to was that many more pupils were completing a full seven year course in the grammar schools. Most of them were taking the General Certificate of Education at "A" level, with or without scholarship papers, and were looking forward to continuing their educa-

tion at universities, technical or training colleges, or in industry.

10. This increase of sixth formers meant that there were pupils at the top of the schools more akin in interests and outlook to college students than to school children. Learning had become for them a serious personal obligation and they were also ready to shoulder a substantial measure of individual and group responsibility. Headmasters were quick to take advantage of this growing maturity and to use it to foster the order and discipline that characterised their schools.

11. The two educational developments described above had considerable implications on the use of the buildings where they were noted and for the design of new selective schools. In the first place the smaller teaching groups could use effectively rooms smaller in dimension than the standard size associated with a form of 30 pupils. More of them, however, would be required in a school as a whole. Given these smaller rooms it would be possible to eliminate the many makeshift arrangements that were seen, such as pupils working in alcoves formed by bookcases placed in corridors, in drying rooms and even in roof spaces.

12. Secondly, the various ways of organising the pupils meant that the "form" was no longer the distinctive social unit in a school. Headmasters were experimenting with a number of other kinds of organisation to replace the form of 30. For example, there were schools divided into Lower, Middle and Upper School sections; others where the pupils on joining the school were allocated to one or other of a number of "houses" or "companies" each containing a cross-section in age and ability of the school population. Such an organisation was not intended only as a social grouping, for the staff in charge undertook certain tutorial and pastoral functions on behalf of their pupils as well. All these devices emphasised the need for variety in accommodation. It was clear that large rooms suitable for social purposes and for use by societies organised by the pupils and also smaller rooms where staff and pupils could discuss personal matters together were required. Classrooms of standard size alone could restrict considerably these complex organisations.

13. The wide age range of pupils in the grammar school, and their correspondingly wide range of needs and interests, also suggested that the accommodation provided for the different age groups might vary in form and character. It was understood that first and second year pupils are broadly identifiable as a homogeneous group in terms of social and physical requirements. Third, fourth and fifth year pupils, in turn, find the interests and pursuits of the younger pupils progressively less satisfying and require different kinds of facilities, while sixth formers, on the threshold of maturity, have a special range of personal and group problems to resolve. Headmasters agreed that within the limitations of the school buildings they used, they tried to produce variety of physical environment for each phase of school life.

14. One headmaster instanced the younger pupils coming from a junior school where life was centred mainly in a single large teaching space, with one teacher. These children tended to feel lost when faced by the sheer size of a large secondary school, the complexity of its organisation and multiplicity of its teachers. He tried to counter this feeling by selecting teachers who could be

responsible for several subjects with the same form of first or second year pupils, but he pointed out that this restricted his freedom of choice of specialist staff. If the younger pupils could be given a sense of security within self-contained accommodation not too different from that to which they were accustomed but related to the specialist rooms they would soon learn to use, then the buildings themselves could make a positive contribution to the running of the school and simplify the headmaster's problems when recruiting staff.

15. At the other end of the scale there was plenty of evidence to show that older pupils needed, in addition to a variety of small teaching rooms, something more like a common room or club. Here, sixth formers who might not otherwise meet because of the diversity of their courses could gather together for "elevenses", for discussion of topics of mutual interest, for talks with staff or visitors and for parties or dances.

16. These were among the ideas gleaned by members of the Development Group during their visits to a number of existing grammar schools. The next section describes the brief for the school at Arnold in more specific terms and shows how the design of the building was influenced by the visits of observation.

THE SCHOOL AT ARNOLD

17. The Nottinghamshire Local Education Authority proposed to build several selective secondary schools near the outskirts of the City of Nottingham. The Arnold County Secondary School would be one of these schools. It would provide for the entry of four forms of thirty pupils, boys and girls, each year and, with a sixth form of 120, would have a total of 720 pupils on roll.

18. The Authority had in mind a curriculum shaped into six different strands or courses. These courses were to offer a variety of combinations of subjects and it was the intention to help boys and girls to select one or other combination most suited to their abilities, interests and possible careers. The courses and the sorts of careers for which the courses might provide a full and stimulating general education were described as follows:

(1) general academic—suitable for professions such as teaching, the law, and the arts of music or drama;

(2) general practical—suitable for nursing, dietetics, physiotherapy, and the practical aspects of music or drama;

(3) science academic—suitable for scientific research, technology or medicine;

(4) science practical—suitable for student apprenticeships, trades, etc.;

(5) commerce academic—suitable for business executive work or social sciences;

(6) commerce practical—suitable for secretarial work, retail buying and selling, etc.

19. It was anticipated that during the first two years the work of all pupils would be basically similar. Divergencies on the lines indicated in paragraph 18

would begin to appear in the third year. Courses (1), (3) and (5), the so-called academic courses, would be maintained for a full seven year period; the remainder would last for at least five years.

20. The Authority originally intended that each year of pupils should be arranged into six groups of 20 pupils instead of the normal four forms of 30, thus enabling the pupils to embark at once on the course of their choice. It was realised, however, that this would make heavy demands on the staff and that in any event a period of preparation was necessary during which individual aptitudes and abilities could be assessed before a final selection of course was made. It was therefore decided that the first two years should be organised in eight forms of 30 and that the course of instruction should be of a general nature leading to one of the specialised courses undertaken later on. In the third, fourth and fifth years, however, pupils would have selected the special course they wished to follow and would then be organised in six groups, or courses, per year, each group consisting of 20 pupils. These years, therefore, would be composed of 18 teaching groups instead of the 12 forms more characteristic of grammar school organisation. This was precisely the way in which some of the headmasters consulted by the development team had arranged their schools which were, however, ill-designed to cope with the greater number of groups thus created.

21. The social organisation of the school followed naturally from these teaching arrangements. In the first two years, or "lower school", the forms of 30 would work with their own form master or form mistress who would probably teach several subjects and be concerned with each pupil's general progress. Thus a gradual transition from the junior school to the greater complexities of the secondary school would be secured.

22. During the next three years each pupil would belong to one of the six "middle school" houses. They would have been introduced to this house system during the first two years in the school by being attached to one of the houses for dining. Each house would include thirty boys and thirty girls and would be under the guidance of a house master and a house mistress, whose duties would be predominantly "pastoral". Through them, every boy and every girl during the three years preceding the General Certificate of Education examination would be assured of continuity in tutorial work and in advice on careers and other personal problems.

23. Sixth formers would remain members of their middle school houses but recognition of their responsibilities as school prefects and of their relative maturity would be made by giving them special accommodation in which they could meet as one social group.

24. In addition to these provisions for the teaching and social organisation of the school, the brief contained two other pointers to the design of the building. First that, while providing for traditional disciplines of thought, the school should also lend itself to the development of the less precisely defined disciplines arising from the uses of science and technology in an industrial age. Further, that both should be enriched by the influence of the arts—of music and drama, of painting and sculpture.

25. The second pointer concerned physical education. It was felt that the trend in grammar schools towards the development of individual courses should

be reflected in this subject also. Provision was required not only for the national team games but for general athletic skills. Pupils should have the chance to select for themselves activities which they particularly liked and especially those which they could continue to enjoy after leaving school.

26. These educational ideas, and many more that were voiced during the early discussions, encouraged the team of architects to reconsider the accommodation usually provided for a grammar school and to give special attention to that required for:

(1) general and specialist teaching rooms for groups of twenty and for the particular use of sixth form pupils;

(2) social accommodation in form rooms, houses and common rooms and for dining;

(3) provision for the practice of music, drama and crafts;

(4) accommodation for physical education.

DEVELOPMENT OF THE SCHEDULE OF ACCOMMODATION

27. With some of the educational requirements thus clarified, an image of the accommodation began to emerge. At this stage it was obviously not possible to decide upon precise rooms and areas but the Authority, drawing upon the experience of its officers, specialist advisers and teachers, drafted a curriculum for the school upon which a tentative schedule of accommodation could be based. With this before them, the Authority's officers and the development team discussed in more detail the kinds of activity that might be expected in the various rooms and preliminary layouts were prepared, based on observations of space requirements in other schools and on combined experience.

28. The architects contributed a number of suggestions about the way space could be arranged, juxtaposed or used for a number of different purposes, so that the building should be as flexible as possible in use. One example of this was the way in which the teaching needs of the middle school were linked with space needed for house activities and for dining to give an arrangement of rooms capable of fulfilling all these purposes. As a result there are available, within the framework of any one house, rooms for large or small teaching groups, for the private study of individuals and for staff.

29. The modifications resulting from this careful process of examination and discussion of rooms and their usage provided a transition to the final schedule of accommodation which was based upon a detailed study of the function and layout of each individual room and its relationship to the building as a whole. The three stages are set out in Table I.

30. The Ministry's Development Group is in the position of being able to examine problems of school design and building in a fundamental way. It can draw upon a wide field of experience and devote much time to the investigations. In this respect it is perhaps more favourably placed than the majority of local education authorities, who must forge ahead with the building of schools scheduled in a tight programme.

It is to be hoped, however, that the practice of the Development Group will not be regarded as a luxury unattainable in the carrying out of ordinary programme projects. The principles hold good for all. Collaboration between the "client" and the architect, and all the specialised advisers available to them, should begin before, rather than after, a schedule of accommodation is finally settled. Collaboration inevitably involves compromise—the architect refining the plan to meet educational needs more closely and the client adjusting his detailed requirements in the context of the developing scheme. Provided the ultimate users of the building, i.e. the staff and the pupils, are always the first concern of both parties there is every chance that the building will provide an environment which is educationally, visually and technically suitable for its manifold purposes.

Table 1. Development of Schedule of Teaching Accommodation

(Minimum nett teaching area required by Standards for School Premises Regulations 1954 = 32,120 sq. ft.)

	Preliminary list based on draft timetable			Modified list after general examination of social and staffing questions			Areas as planned		
	No. of spaces	Area	Total area per group	No. of spaces	Area	Total area per group	No. of spaces	Area	Total area per group
Hall	1	3,000		1	3,000		1	2,800	
Gymnasiums	1	3,000		2	4,000*		2	3,950*	
			6,000			7,000			6,750
Library	1	1,500		1	2,000		1	1,667	
reading room							1	452	
			1,500			2,000			2,119
General teaching rooms									
houserooms				6	720		6	530†	
classrooms				8	480		8	510	
	20	400		5	400		5	369	
							1	547	
							1	313	
	1	260		6	240		2	250	
	7	240					2	208	
							2	61	
			9,940			11,600			11,003

*This is partly made up of an indoor space of normal construction and partly of a special covered space—the latter measuring 8,430 sq. ft. but counting nominally as 1,600 sq. ft. of the schedule, (see paragraphs 62–64).

†Part of the 683 sq. ft. houserooms ascribed to teaching.

Specialised teaching rooms									
music rooms	1	1,000		1	800		1	772	
							1	120	
				1	80		1	79	
				2	60		1	58	
							1	38	
demonstration room	1	720		1	720		1	673	
geography room	1	720		1	720		1	751	
technical drawing room	1	600		1	720		1	673	
maths. laboratory	1	720		1	720		1	506	
commerce room	1	720		1	720		1	673	
			4,480			4,600			4,343
Laboratories	6	720		1	960		1	901	
				5	720		5	673	
optics room							1	154	
			4,320			4,560			4,420
Craft	6	960		1	3,600		1	4,432	
			5,760			3,600			4,432
Grand Total			32,000			33,360			33,067
+ dining			1,290						
			33,290						

DEVELOPMENT OF THE PLAN

31. The school site (see plan) lies on the southern outskirts of the town of Arnold, about four miles from the centre of Nottingham, and adjoins that of a two-form entry girls' secondary modern school (to be built a few years later) and the playing fields both for that school and for a boys' secondary modern school situated elsewhere in Arnold.

32. The area is almost completely surrounded by fine thick hedges interspersed with several well grown oak and ash trees. It falls steeply from north to south, with an average slope of 1 in 13, the land beyond the southern boundary rising again to form a pleasant hillside prospect with distant views of the outskirts of Nottingham.

33. The grammar school was placed on the western part of this area, and the following objectives governed the disposition of the buildings:

(1) the library, as the intellectual centre, and the assembly hall as the communal meeting place, should form the kernel of the school buildings;

(2) the social accommodation—form-rooms, houserooms and common rooms—should be grouped immediately around this kernel. In order to achieve the scale and environment appropriate to each group, the accommodation should be clearly defined; the lower school, middle school and sixth form should each have its own entrances and outdoor spaces;

(3) because of the sometimes severe

climate the buildings should be arranged to form a number of sheltered courtyards, which would serve as the most direct circulation routes in normal conditions. For occasional use in bad weather, there should also be internal circulation throughout the school and wherever possible there should be associated with this circulation small study bays suitable for two or three pupils;

(4) if possible, without prejudicing the above objectives, the external wall, normally an expensive item, should be kept to a minimum by making the component blocks of the school as square in shape, and with as regular a perimeter, as possible.

34. In the remainder of this section the main groups of spaces will be discussed in turn.

Table 2. Plan Analysis†

Item	Accommodation	Area sq. ft.	Area per place sq. ft.	Percentage of total
1	Gross teaching area	34,245	42·0	57·0
2	Teaching storage	2,796	3·4	4·7
3	Dining‡	595	0·7	1·0
4	Storage of pupils' belongings, Sanitary accommodation for pupils	4,878	6·0	8·1
5	Administration	6,922	8·5	11·5
6	Circulation	9,325	11·4	15·4
7	(a) Covered ways (½ actual area)	335	0·4	0·5
	(b) Porches, recesses, etc. (½ actual area)	1,176	1·5	1·8
8	Total superficial area	60,272	73·9	100

†Areas measured to centre lines of partitions.
‡Part of dining area only: remainder under item 1.

THE HALL

35. In many of the schools visited during the investigations, it was noticed that the hall was not fully used and sometimes stood empty—a remarkable sight in a busy, often overcrowded, school. In other instances, however, the hall was in constant use, both during and after school hours. In addition to the daily assembly, there might be class instruction in music and drama, meetings of school societies, physical education or dining. In one school the hall was used at lunch time as a general, informal meeting place, where the boys went to talk or read newspapers and to see an occasional lunch-time film show.

36. Apart from the preferences of the headmaster about the way the assembly hall was used, the size and character of the building itself also had their influence. The long, narrow, usually lofty halls, equipped at one end with a high and elaborate stage, had obviously been designed primarily for assembly and for proscenium drama. Their size (many were considerably more than 3,000 sq. ft. in area), the cliff-like walls and the poor acoustic qualities made these spaces unsuitable for informal use by small groups.

37. There was general agreement amongst headmasters that the hall should be capable of being used fully in a variety of ways. and, provided that it was designed so that the noisier activities should not interfere with other teaching rooms, placed centrally among the school buildings.

38. Following these recommendations, the hall at Arnold is designed as the social focus of the school. It is placed in the middle of the school and provides an area

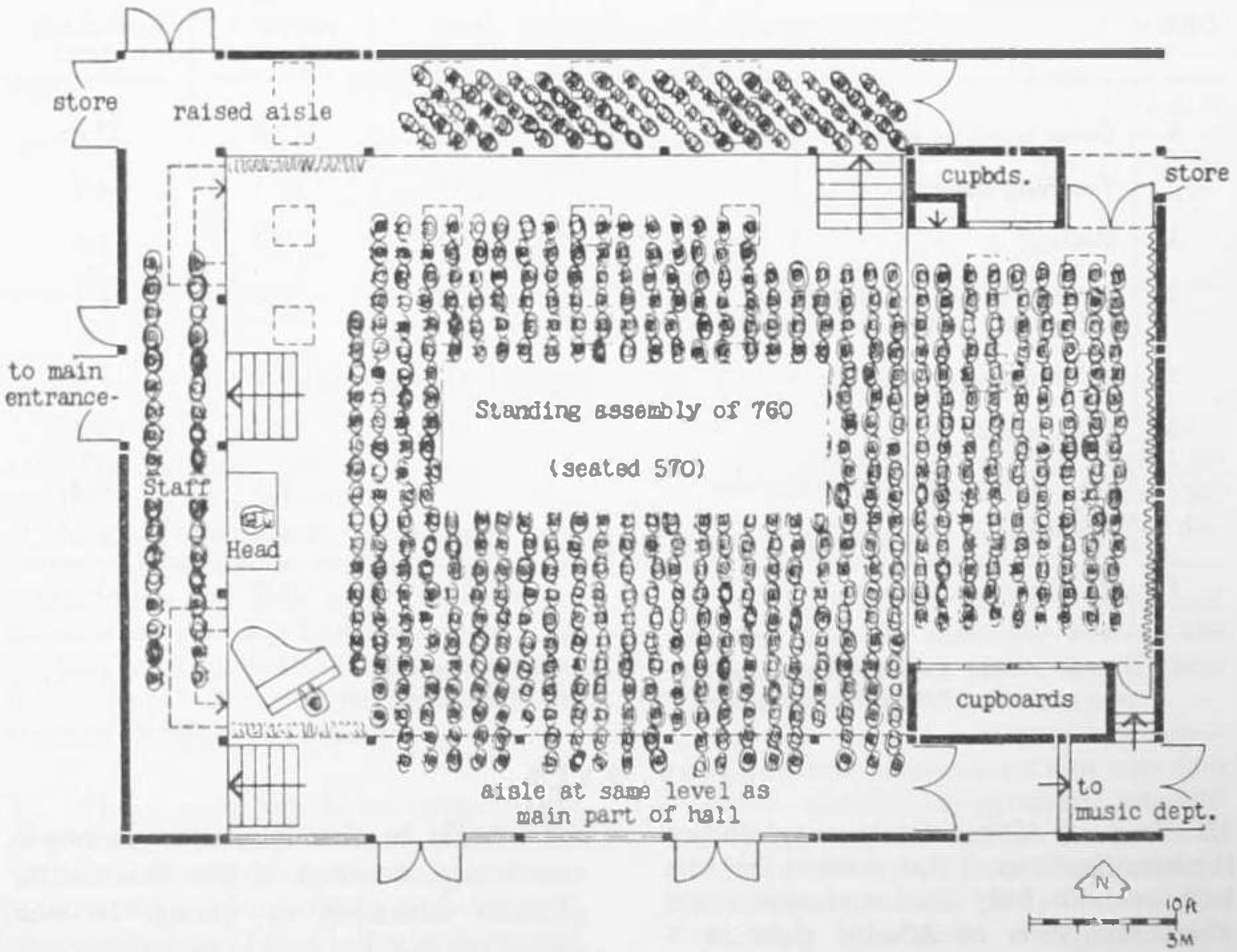


Diagram 1. HALL—School assembly
Area: 2,800 sq. ft.

of 2,800 sq. ft. for assembly, music and drama. The aisles can be used for circulation between teaching periods. This, together with variations in floor and ceiling levels, and the use of rich and lively wall materials such as curtains and wood-strip panelling (which also serve an acoustic purpose), should save the hall from a feeling of bleak emptiness which might well inhibit its general use.

39. The hall will accommodate a standing assembly of the school. (See diagram 1). One of the aisles is more suitable than the stage as a platform for a single speaker, leaving the much larger stage for part of the audience. All the stage equipment is demountable and there is no fixed proscenium, so that there is no difficulty about this arrangement.

40. It will be noted that no attempt has been made to provide for a seated assembly of the school. There were two reasons: in the first place, assemblies of the whole school account for only a small

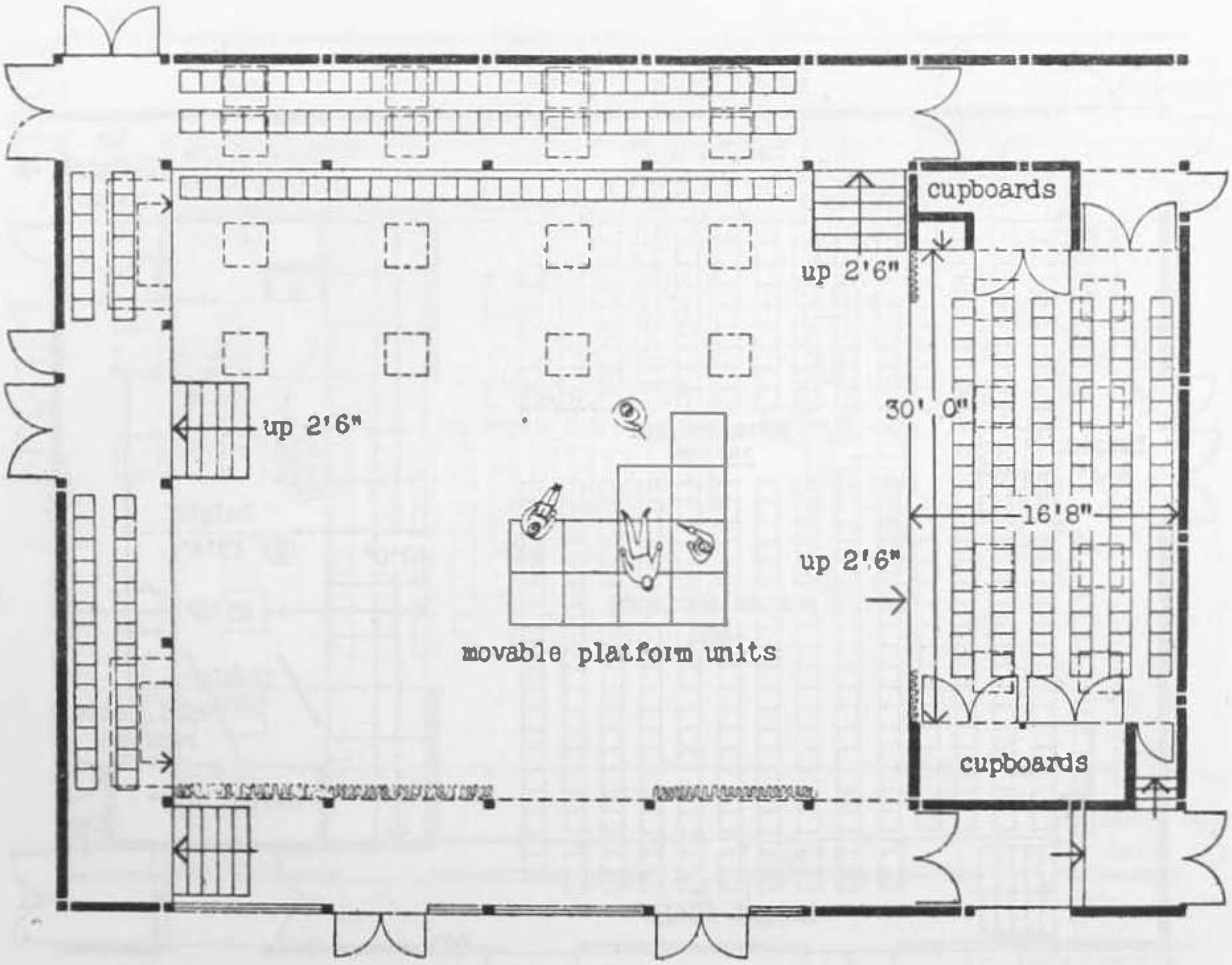


Diagram 2. HALL—class drama
Seating is shown for a small audience, as placed for a 'drama in the round' performance

part of the use of the hall and, secondly, the area needed to accommodate a seated assembly would produce a hall unsuitable, because of its great size alone, for the many other activities for which it is needed.

41. One of the foremost uses of the hall is for drama. Two kinds of dramatic activity have been allowed for in the design of the hall at Arnold. There is the day-to-day use, in which a class might use the hall for a play-reading or for mime. They might, in small groups of three or four, use the aisles, or the stage itself, or a set of movable platform units, 10 ins., 1 ft. 8 ins. and 2 ft. 6 in. high, which can be used in association with the stage or the aisles or in free standing arrangements on the floor of the hall. (See diagram 2).

42. The second form of dramatic activity to be taken into account is the larger scale, more finished, production, in which the talents of the pupils as scene painters, costume makers, electricians and front of house managers might figure as largely as those of the actors themselves. There

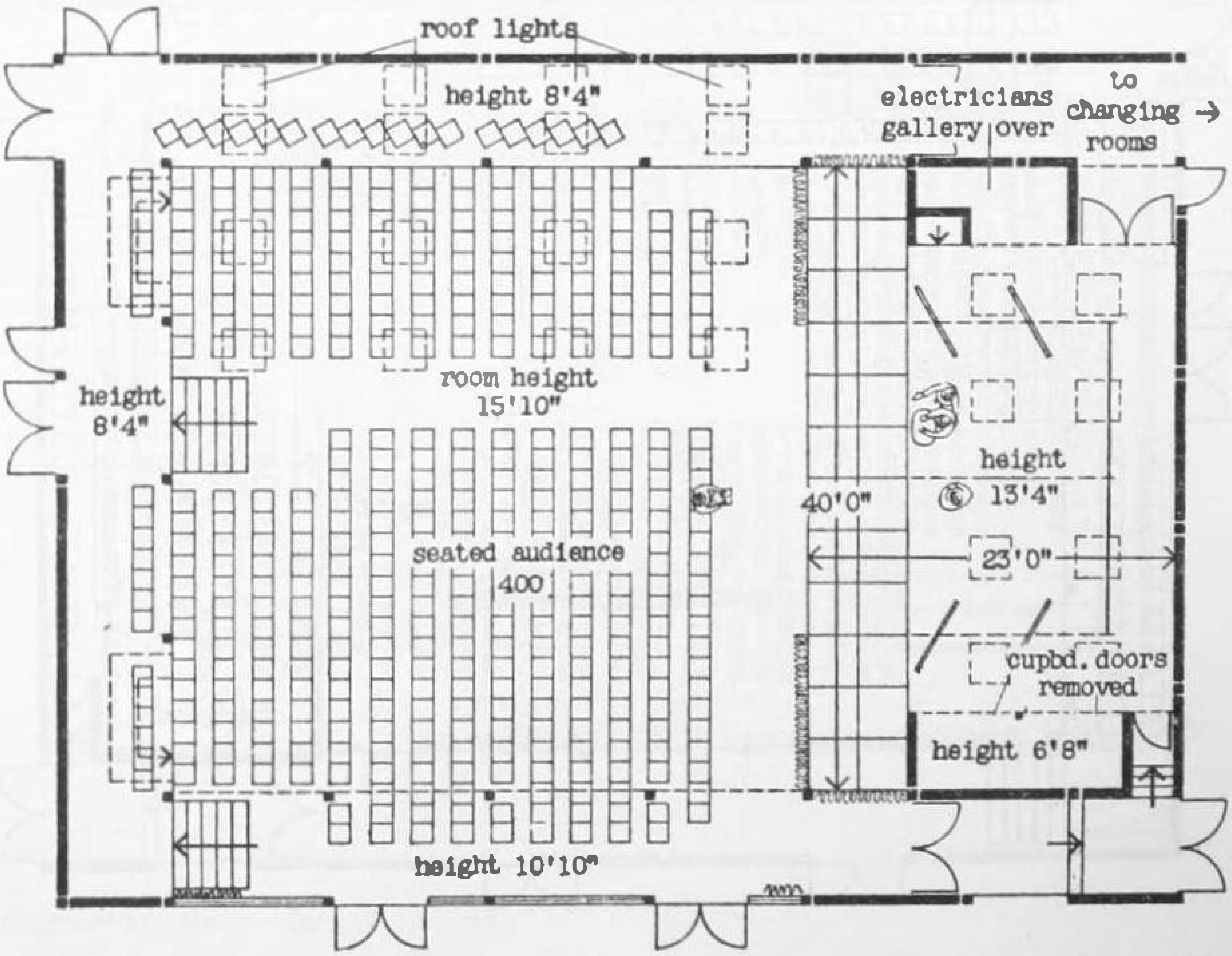


Diagram 3. HALL—drama performance

would almost always be an audience at this kind of performance, increasing the sense of a special occasion. (See diagram 3). Continuous fixing rails for the stage equipment run from back to front of the stage ceiling and the proscenium curtains, which normally hang, for visual and acoustic reasons, at the back of the stage, can be hung on a demountable track, fitted with winch operated gear. With the full stage thus in commission, the hall will seat an audience of about 400, at a maximum distance of just over 40 ft. from the stage, which is as much as children can cope with when acting. (For stage lighting, see paragraph 197).

43. The stage can also, of course, be used for a choir or orchestra, as it is completely open to the hall, with no fixed proscenium to form a baffle. The flat surface of the stage can be used as it is, or the movable platform units can be built on to it to form three wide tiers. (See diagram 4).

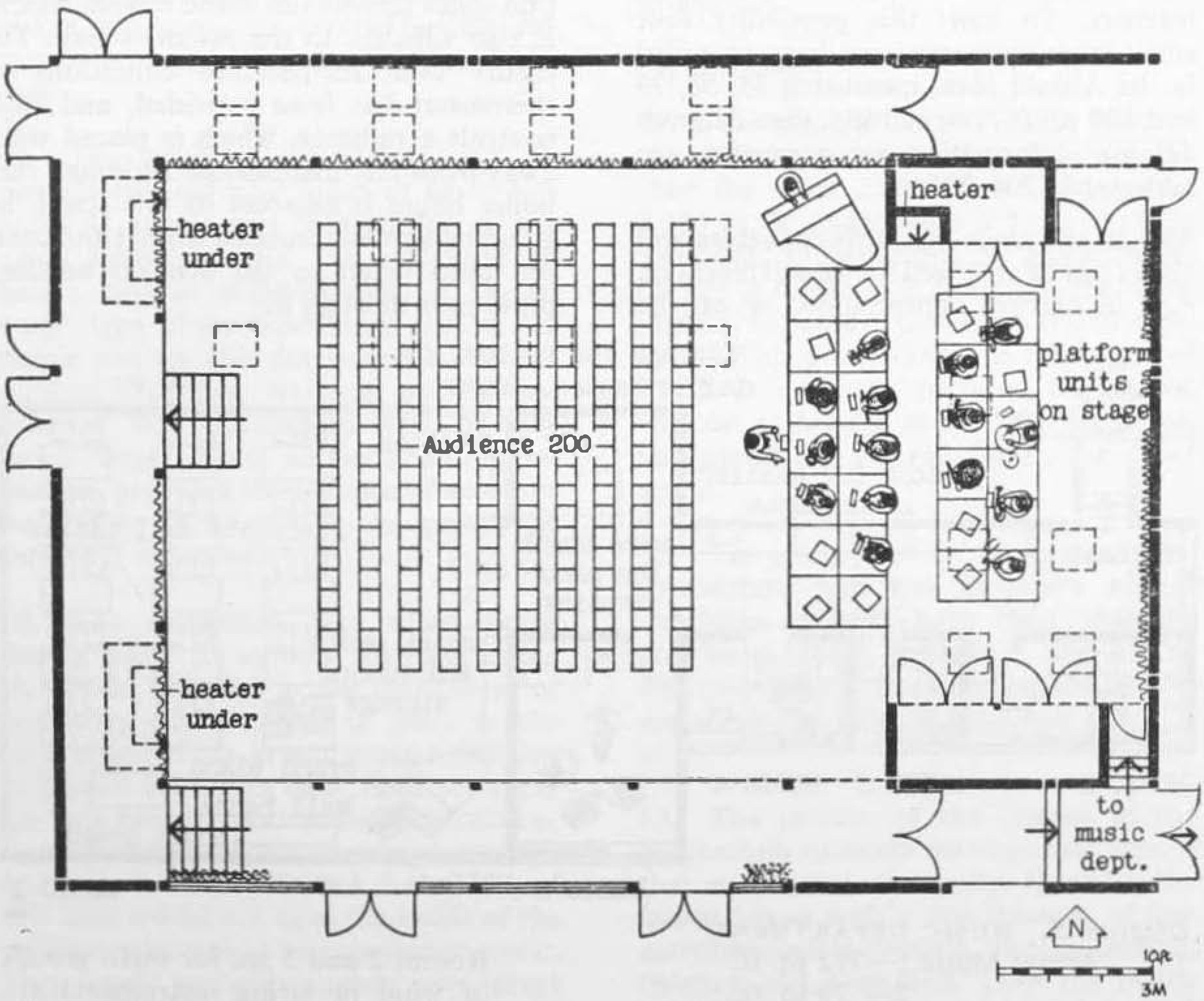


Diagram 4. HALL—orchestral performance
Platform units are arranged at floor and stage levels to form raked seating for orchestra or choir

MUSIC ROOMS

44. The small hall has been designed mainly for music. It will, however, seat an audience of 100–120 so it could also be used for lectures, when for instance, the headmaster or a visiting speaker wished to speak to the pupils of one year.

45. During visits to other grammar schools it was noted that, in addition to music periods for whole classes, there might be a considerable number of lessons for small groups and even individual pupils, often given by visiting teachers. To meet this possibility four small practice rooms have been provided in the Arnold plan, measuring 38, 58, 79 and 120 sq. ft., respectively. (See diagram 5). For information on acoustics, see paragraphs 204–206.

46. In the main music room, tables and chairs can be arranged for formal teaching, e.g., in musical appreciation, or can be stacked away so that the pupils can be grouped for singing or orchestral playing.

47. The musical instruments themselves present problems of storage. They will be used both in the music room and in the assembly hall, in and out of school hours. Some may belong to the pupils, and will be brought to school as needed, others will be the property of the school and either kept at the school or lent out. Storage facilities have been provided in a circulation space serving the music rooms, which is also adjacent to the assembly hall. To ensure even temperature conditions a thermostat has been provided, and this controls a radiator, which is placed well away from the instruments. Although the boiler house is adjacent to this space, it is thermally well insulated from it and care has been taken to see that no heating pipes pass through it.

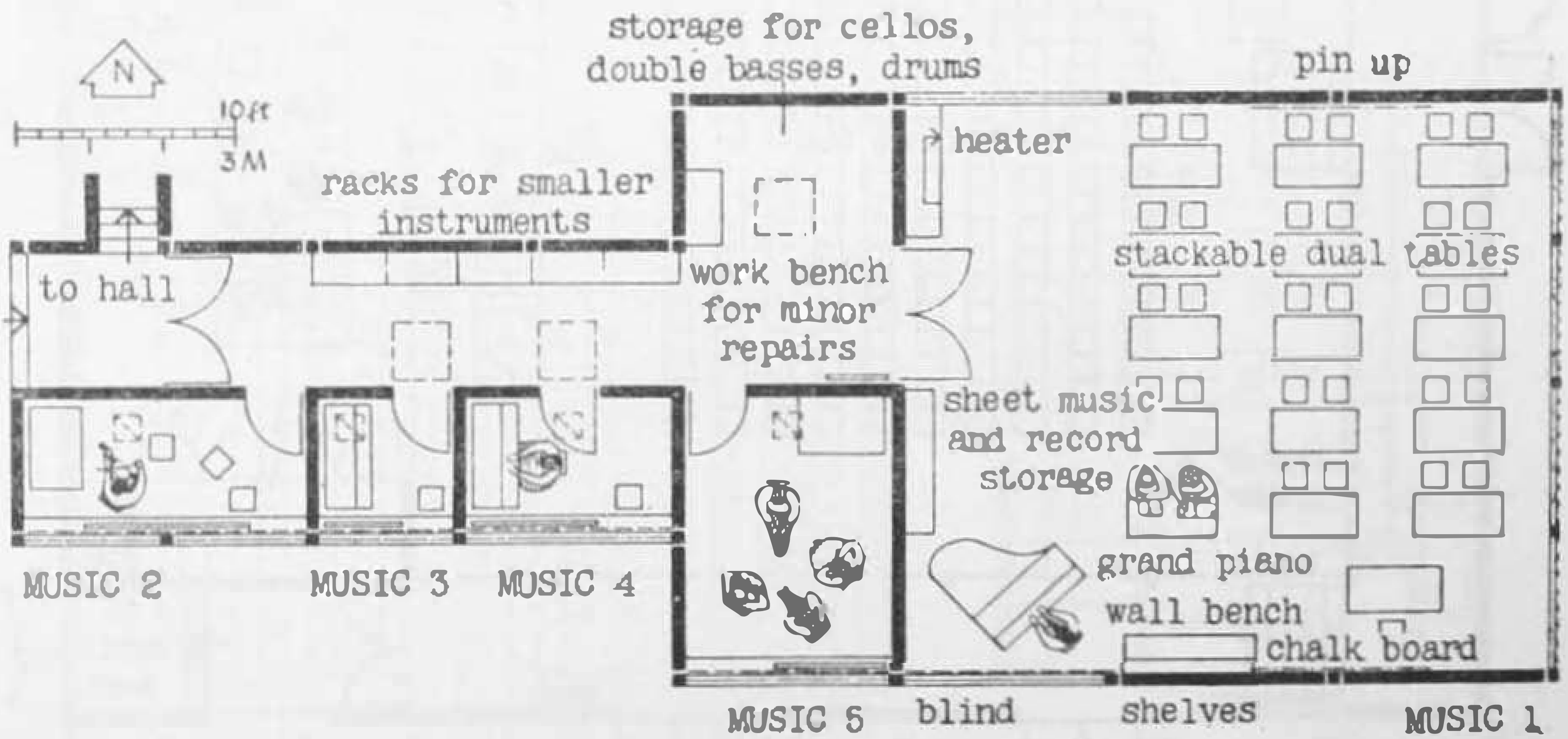


Diagram 5. MUSIC DEPARTMENT

Areas: Music 1—772 sq. ft.
2— 79 sq. ft.
3— 38 sq. ft.
4— 58 sq. ft.
5—120 sq. ft.

Rooms 2 and 5 are for small groups of wind or string instrumentalists. Rooms 3 and 4 are equipped with upright pianos for individual lessons or practice

ACCOMMODATION FOR PHYSICAL EDUCATION

General

48. The usual provision for physical education in a new school of this size would be two gymnasiums each of 2,800sq ft. These spaces would be used for such activities as gymnastics, dancing, music and movement, basket-ball and badminton. At Arnold, as has been mentioned in paragraph 25, the client had in mind an even wider variety of activity, including athletics training, cricket practice and tennis, and, moreover, wanted facilities for these to be carried out throughout the year.

49. The solution arrived at was to provide two different kinds of space (see plan)—a gymnasium to cater for all the usual activities with the exception of games, and an athletics shed—a "dutch barn" type of structure large enough for tennis and suitable for basket-ball, badminton, athletics training and games practice. This latter space could be very much larger than an orthodox gymnasium, provided the balance of cost was restored by its being partially open at the sides and unheated.

50. The suggestion was often heard during visits to schools that swimming should be included in the curriculum of secondary schools, and in fact, in the early stages of the Arnold project, the idea of a small swimming bath, suitable simply for elementary swimming instruction, was considered. Closer examination of the question, however, showed that a bath of this kind would not meet the needs of the children who would be expected to use it. They would probably already have learnt to swim and would now want facilities to develop their skill at it and also to start diving. To do the job properly, therefore, a proper swimming bath was needed, of full size and with filtration and heating plant. But the cost of providing a bath of this kind would have raised an acute problem. In fact, it became clear that a large amount of physical education facilities would have to be sacrificed, and the athletics shed in particular would certainly have to go. For these reasons the idea of a swimming bath had to be dropped.

Gymnasium

51. The gymnasium at Arnold was, on the client's advice, made rather smaller than the usual 2,800 sq. ft.; it provides 2,350 sq. ft. and measures 59 ft. 6 in. by 39 ft. 6 in. (these dimensions, and all others quoted in this section, are measured to the internal surfaces of partitions and external walls). This was because the full length of 70 ft. is normally required for games, whereas at Arnold, as has been explained, the games are catered for in the other space.

52. The question of the apparatus in the gymnasium was also examined afresh. Teaching methods have been changing and have moved towards a less formal and more experimental approach, but the apparatus has not changed very much, if at all.

53. The pattern of the lessons in the gymnasium varied in detail in each school that was visited. Generally, however, the lesson began with a few minutes of free activities such as running, leaping, curling, twisting and stretching. Then the pupils would split into groups, each of about 5 or 6, and set up an arrangement of

apparatus. For the younger ones the teacher would have a simple arrangement, such as a bench hooked on to a beam, or wall-bar, to form an inclined plane up which they would run before jumping off, but as the pupils became more experienced so the arrangement of apparatus became more complex and ropes, beams, wall-bars, benches and horses came into play.

54. It was noticed that wall-bars were not used for hanging exercises by the whole class at once. Their main use appeared to be as fixing points for benches. Ropes, beams, benches, horses and boxes seemed to be the most commonly used pieces of apparatus and great ingenuity was shown in connecting the apparatus so that pupils could perform a continuous series of movements through, under or over them. Even so, the apparatus was never flexible enough. Teachers wanted, for instance, to be able to place ropes at right angles to another set, and to have ladders which could be fixed horizontally, vertically or in an inclined plane or on edge. In fact they wanted something to correspond in scope and flexibility with the agility apparatus used in junior schools.

Gymnasium equipment

55. The main problem was to design apparatus of suitable stability which would be easily and quickly demountable. Head and foot fixings are provided at 6 ft. 8 in. centres to allow the erection of 15 ft. vertical aluminium alloy poles. Although connections are available for a maximum of 17 poles, the staff are free to select the numbers and locations to suit a particular lesson. (See diagram 6).

56. Each pole is quickly erected by two pupils. One locates the foot in a component set in the floor, while the other

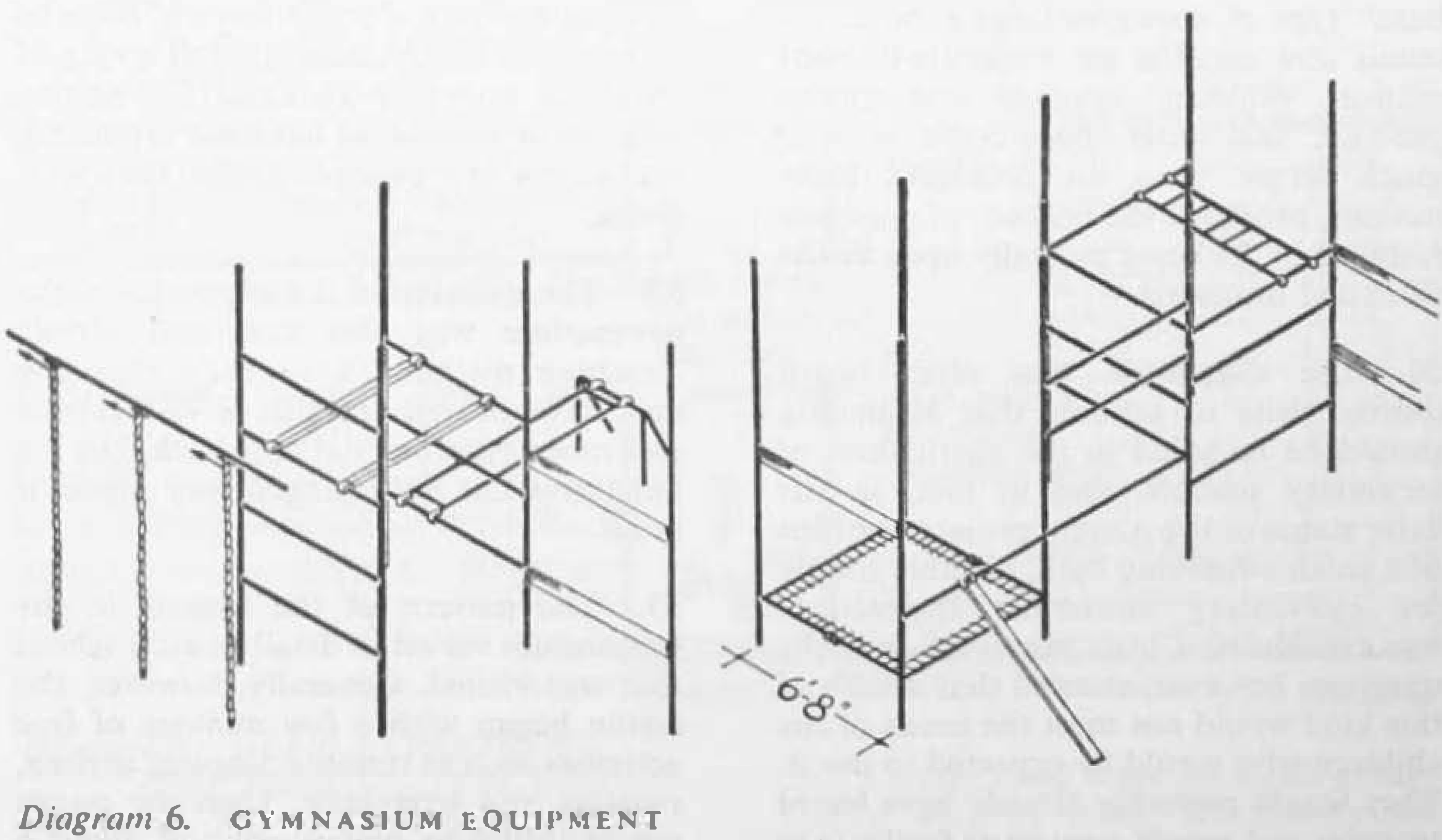


Diagram 6. GYMNASIUM EQUIPMENT
Showing two only of the many arrangements possible with this equipment

pushes the pole into a vertical position. It is safely locked by a small gate mechanism mounted below the ceiling which is fitted with a green warning light wired to operate when the gate is closed and safe. This locking device can only be released by electrical means and the pupils taking down the pole will be warned by buzzer when the gate is about to be freed; the green safety light will go out when the release is operated.

57. These poles provide fixing for 6 ft. 8 in. and 13 ft. 4 in. beams which can be connected to the poles in straight lines or in 2, or 4 directions at right angles to one another, up to 12 ft. above the floor. Planks and ladders can be attached to the beams to achieve inclined surfaces at varying heights. Rope ladders, rings and trapezes can also be suspended.

58. A series of stools give beam and plank connections at low level. These can either be used independently or in association with the main structure.

59. A line of 6 ropes is mounted across each end of the gymnasium, approximately 13 ft. 4 in. away from the end wall.

60. The gymnasium is lit principally by rooflights in order to give an even illumination throughout; in addition, there are south facing windows, fitted with wired glass and protective bars, running up from 3 ft. 4 in. to a height of 10 ft., through which there is a wide view of the playing fields.

61. The floor is covered with poly-vinyl-acetate tiles with a pimpled surface (see paragraph 200).

Athletics shed

62. In the athletics shed, space had to be provided for tennis, netball, basket-ball, badminton, and general games and athletics practice. It was obviously impossible, within the cost limits, to provide a structure large enough to allow all these activities to take place simultaneously, nor would it ever be necessary from the school's point of view. In order, however, to provide as large an area as possible, it was decided to use a standard form of structure, developed in fact for agricultural purposes, which would be cheaper than a specially designed structure.

63. The athletics shed thus takes the form of a "dutch barn" with a span of 75 ft. and a length of 116 ft., giving a total usable area of 8,430 sq. ft. The roof continues 5 ft. beyond the span, sloping downward to give protection against rain. The height of the shed, to the underside of the trusses, is 20 ft. Most of one end of the shed is bounded by a full height wall, the other by a 9 ft. wall. The floor of the shed is covered with tarmac. Nets can be arranged to divide the various activities from one another.

64. While primarily designed for games and athletics, this shed can fulfil another purpose—as a kind of marquee on speech days or similar functions. While, as explained in paragraph 40, the assembly hall has been deliberately limited in size, the athletics shed provides plenty of room—it can seat 1,600, which will allow every pupil to be present and to bring at least one parent. To allow for this kind of assembly the loudspeaker apparatus provided for the hall is demountable and can be erected in the athletics shed.

THE LIBRARY

General

65. In most of the schools visited, the library was used mainly for private study. For example, in one four-form entry school, as many as sixty pupils were seen working on their own with "the air of students for whom the business of learning is now a personal responsibility".* Generally most of the pupils using the library in this way were sixth-formers (those studying literature, languages or history often spending as much as half their time there), but sometimes fifth-formers and even fourth-formers were to be found.

66. Because the library was needed increasingly for private study, head teachers found difficulty in setting aside periods during which the younger pupils could use it. Nevertheless they considered it vital that from the time the children entered the school they should be made to feel at home in the library, that they should not only learn how to find their way about the shelves but that they should come naturally to consult books, whether in connection with their school work or as a matter of private pleasure. In this way there would be no break from the child's experience in the junior school, where there is a growing tendency to provide library facilities.

67. Outside school hours, many school libraries were thronged with readers; in others they were quite empty and even, in one or two cases, locked. Sometimes the location and character of the room influenced its use—a large classroom-like place, in an isolated position, was obviously less inviting than a room with, for instance, reading alcoves and upholstered armchairs, situated near the centre of the school. The freedom of pupils to use the library is, of course, a matter for the school to determine, but not much can be done about its location—though one school with the library at the end of a wing of classrooms had mitigated this disadvantage by having a number of stands for newspapers in a central circulation space.

68. At Arnold, the library, which totals 1,667 sq. ft. in area, is located centrally, and has been planned as two separate working areas linked by a third space which contains most, but not all, of the book stacks. (See diagram 7).

General library

69. One of the working areas has been designed as a general library for use by classes of twenty or thirty. The aim, however, has been to make it different in character from a classroom, as the library is meant to occupy a unique position in the school. The walls are lined with books and there are large tables at which pupils can spread their books in comfort. The cork tiled floor, and the window-curtains, will, it is hoped, contribute richness and vitality and, at the same time, reduce the level of noise. Window-seats and easy chairs have been provided to encourage the use of the library for private reading outside school hours. At one end of the library there is a small bay in which books of particular interest to the younger children may be kept. There is a librarian's table, with card indexes and catalogues near it, so that pupils may be shown how to find books; also, of course, there may

*Ministry of Education Pamphlet No. 21: "The School Library". (H.M.S.O. Price 3s.)

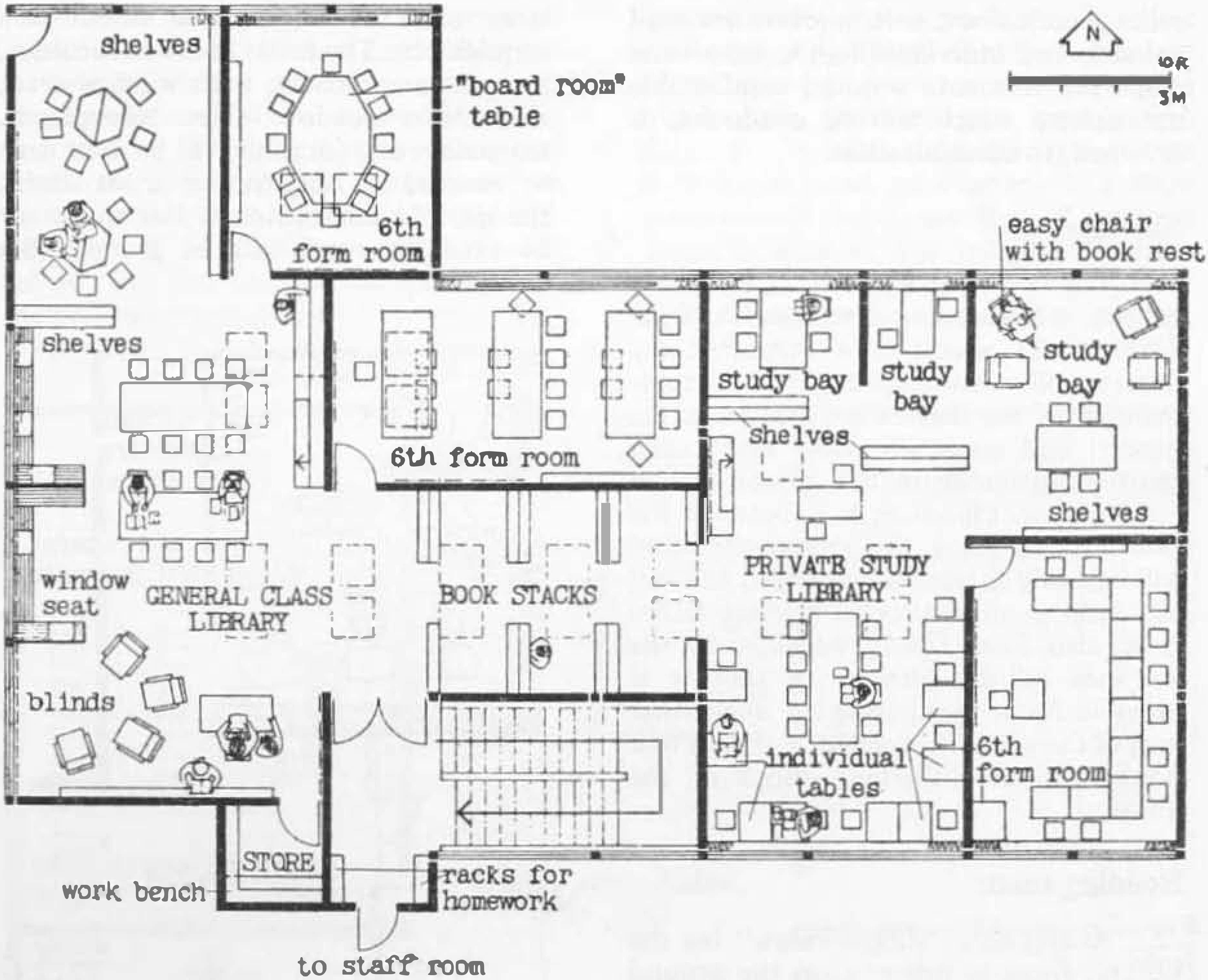


Diagram 7. LIBRARY
Area: 1,667 sq. ft.
The 6th form rooms and study bays are not included in this area

be a lending service run by the pupils themselves.

Study library

70. The second working area has been designed as a private study library. Here the needs of the older student have been the main consideration. A number of single tables, each 2 ft. 6 in. by 2 ft. and fitted with a desk lamp, have been provided. To give the space a quiet and secluded air, it has been divided by partitions and book stacks into a number of small bays. As some students may spend the greater part of their day in it, the room has been given a south aspect, so as to get as much sun as possible. Translucent curtains are provided for the main windows. The space opens on to a small roof terrace, which may be used during hot weather. Sound absorbent

ceiling, cork floor, soft. unobtrusive wall colours, and individual lights, have been employed to create a quiet, comfortable atmosphere which will be conducive, it is hoped, to concentration.

Storage

71. The book stack space, or reference section, will accommodate about half the 7,000 books which it is estimated the library will eventually contain. The remainder of the shelves are located in the general and study libraries. More shelf space is available in the adjacent sixth form rooms. Placed as it is between the two working areas, this reference section will be easily accessible from both and will also help to absorb sound between them. It is also immediately adjacent to the entrance of the library, so that it is possible for a pupil working in another part of the school to come in and refer to a book without disturbing those in the library.

Reading room

72. Acting as a "shop-window" for the library, there is below it on the ground floor, immediately adjacent to the entrance hall, a reading room of 452 sq. ft. It is placed so that everyone will be aware of it as they move about the school. Pin-up boards and shelves have been arranged to form a background for library exhibitions and for information about new acquisitions. The room has been furnished as a common room, with window-seats, easy chairs and low tables. Newspapers, magazines and journals will be kept here, to be read as opportunity arises during the day. In school hours, this space can be used for small tutorial groups. (See diagram 8).

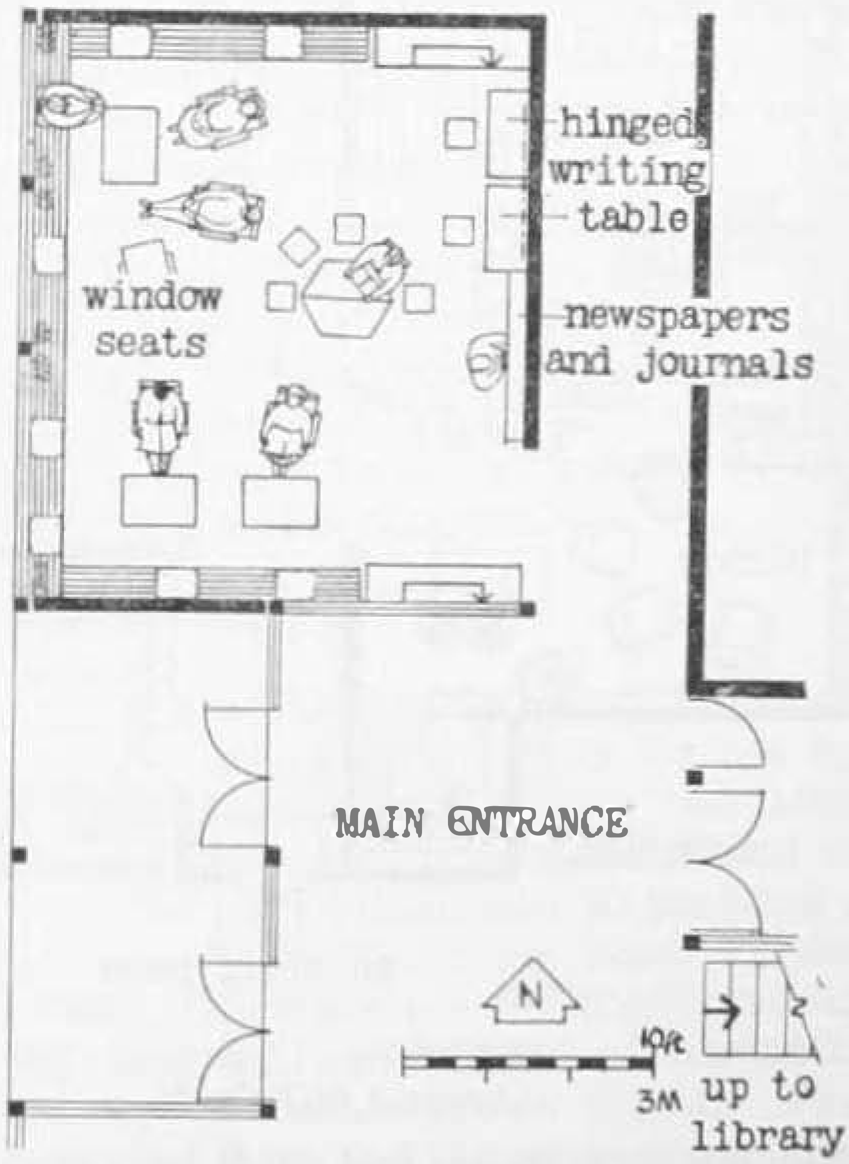


Diagram 8. READING ROOM
Area: 452 sq. ft.

GENERAL TEACHING SPACES

73. At Arnold, all the general teaching spaces have been designed to serve also as social spaces (house-rooms, etc.). It is, therefore, convenient to consider them in the context of the social organisation of the lower school, middle school and sixth form.

Lower school

74. In the lower school there are eight

rooms each 510 sq. ft. in area and measuring 26 ft. 2 in. by 19 ft. 6 in. In this size and shape it is just possible to arrange all the necessary wall-benching and furniture for a class of thirty, but there is little room to spare. These classrooms are equipped with dual tables, measuring 3 ft. 8 in. by 1 ft. 10 in.; these, and the chairs, follow the British Standard anthropometric recommendations.* In the four rooms for the first year, books, etc., are stored in lockers attached to the tables (see plate 13), while for the other four rooms lockers are provided just outside (see Plate 8). In both cases the size of the locker was based on a survey of storage requirements in a number of existing grammar schools. The volume of storage required is, of course, considerably greater than is necessary in secondary modern

*B.S.3030: Part 3: 1959.

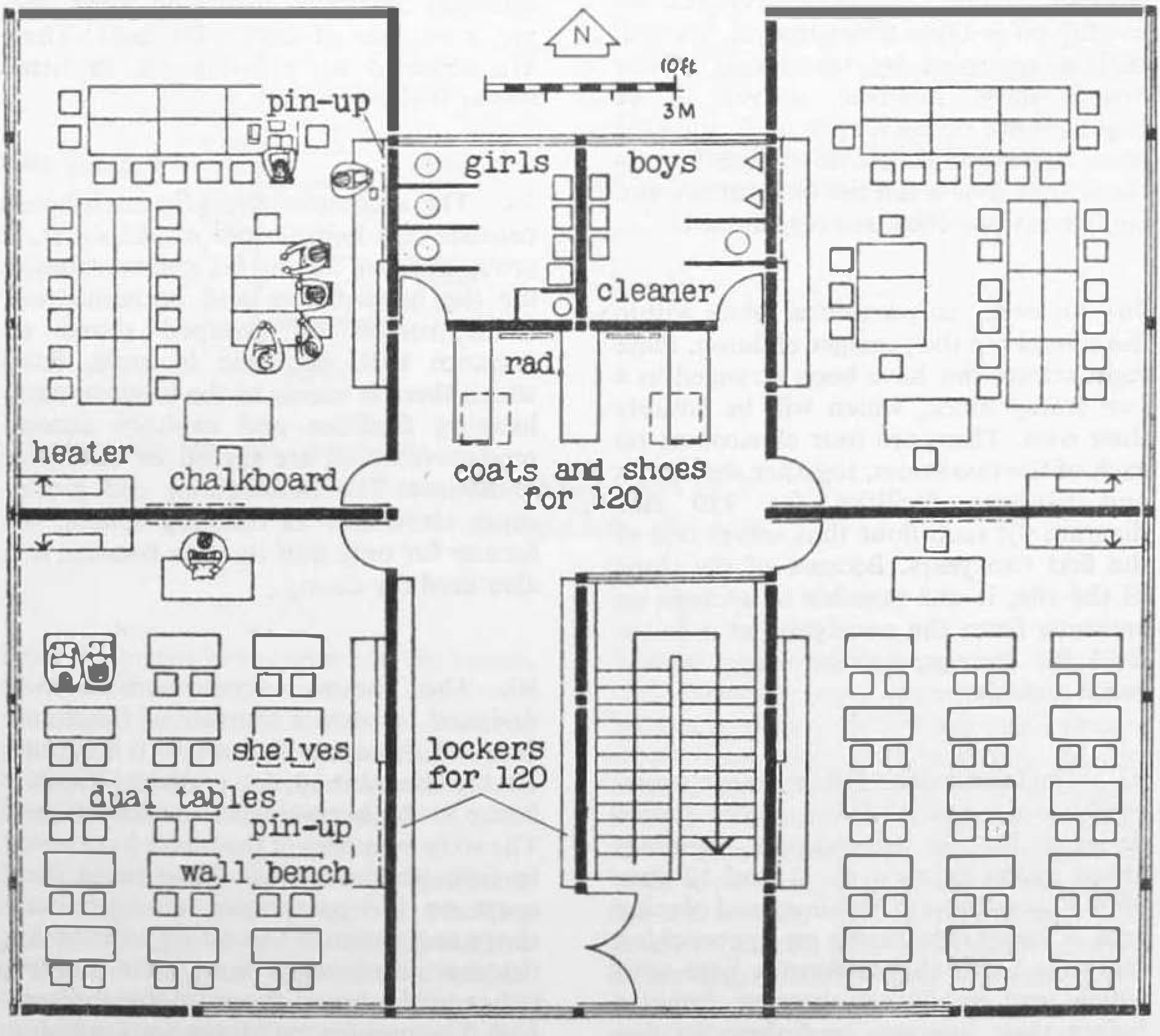


Diagram 9. LOWER SCHOOL—second floor
Area of classrooms: 510 sq. ft.

schools, because each pupil has his own exercise and text books, atlas, drawing instruments, etc.

75. General class storage is provided in wall-benches, fitted mainly with shallow trays, but with a few shelves for larger objects. (See plate 9). Chalkboards are of the sliding and hinged type, which has the advantages that the teacher can raise or lower the board into a comfortable position, and that the surface available for writing on is three times that of the wall surface occupied by the board. These boards have, however, proved to be slightly more expensive per sq. ft. than the cloth roller boards provided elsewhere in the school. For a full list of furniture and equipment provided, see Appendix 1.

76. In order to provide a home within the school for the younger children, these eight classrooms have been arranged in a two storey block, which will be entirely their own. There are four classrooms on each of the two floors, together with coats and sanitary facilities for 120 (see diagram 9); each floor thus serves one of the first two years. Because of the slope of the site, it was possible to arrange an entrance from the courtyard at a lower level for storage, service rooms and a small tuck shop.

77. The fourth side of the entrance courtyard is open and leads on to play spaces designed for the adventurous, running-about games enjoyed by 11 and 12 year olds. This nucleus of buildings and playing area is easily identifiable on approaching the school and should form a base with which new pupils can become familiar before their interests lead them to discover, and become a part of, the whole school.

Middle school

78. The general teaching spaces for the middle school are arranged to form the accommodation for six houses, each of thirty boys and thirty girls drawn from the third, fourth and fifth years. As with the lower school, these pupils have a special entrance to their part of the school buildings, and each house can be entered direct from a paved courtyard. This courtyard has a central free area for circulation and informal recreation, while on three sides are a number of bays with seats. These are screened by planting set in tiered flower beds.

79. The accommodation for each house consists of a house-room of 683 sq. ft., a group-room of 369 sq. ft., and two studies for the housemaster and housemistress. These rooms are grouped round an entrance hall, domestic in scale, from which there is access to the kitchen, coat-hanging facilities and sanitary accommodation which are shared by each pair of houses. The house-room and group-room serve also as teaching spaces, the former for only half its time because it is also used for dining.

80. The house accommodation is designed to serve a number of functions. Some of these are illustrated in diagrams 10–13. Diagram 10, for instance, shows a house at the beginning of the school day. The sixty members of the house have come in from the courtyard, have hung their coats on the coat racks, changed their shoes and selected the books needed for the morning lessons from their lockers, either in the house-room or the entrance hall. The register may have been called in two groups of thirty, using both house-room and group-room, or collectively.

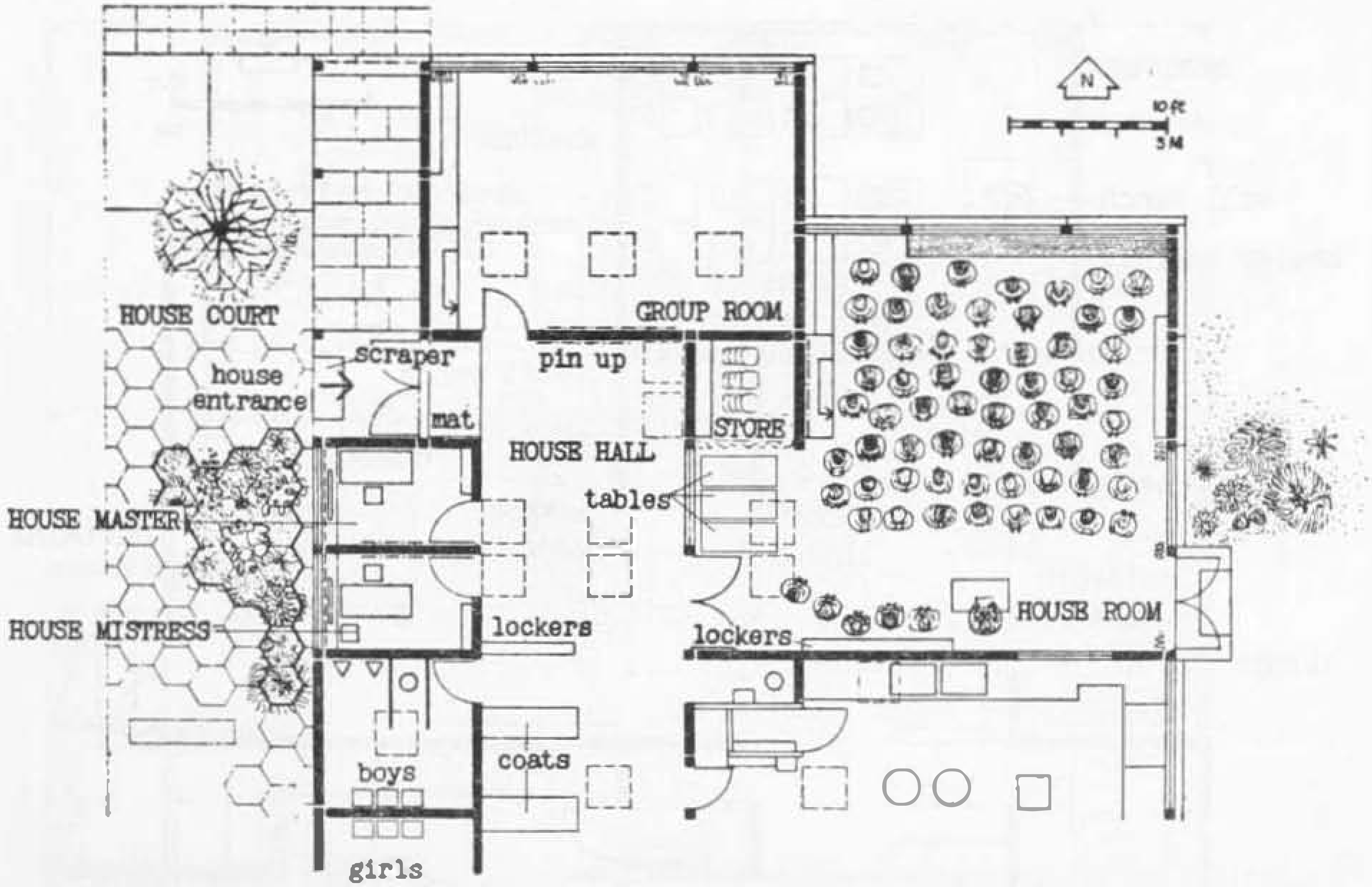


Diagram 10. HOUSE—assembly

Areas: House-room 683 sq. ft.
Group-room 369 sq. ft.

Now the pupils have come into the house-room for a meeting, which may begin with an act of worship. In order to clear the floor for this assembly, the chairs and tables have been stacked in an alcove away from the main windows.

81. Diagram 11 shows the probable arrangement during a typical teaching period. The group-room is being used as a general teaching space for a middle school set of twenty, drawn from the middle school generally, and not from this house alone. The room may well be used frequently for one particular subject, and thus it may have developed its own characteristics, e.g., travel posters in a language room, distinctive wall-charts, displays of newspaper cuttings, etc., in others. Meanwhile, in the house-room there is another set of twenty pupils from the middle school. The larger room area lends itself to subjects needing extra space for movement, e.g., play-reading. The house-room can also be used for groups larger than twenty, thus allowing additional flexibility in the arrangement of the timetable. Both house-room and group-room are equipped with storage and display facilities similar to those in the lower

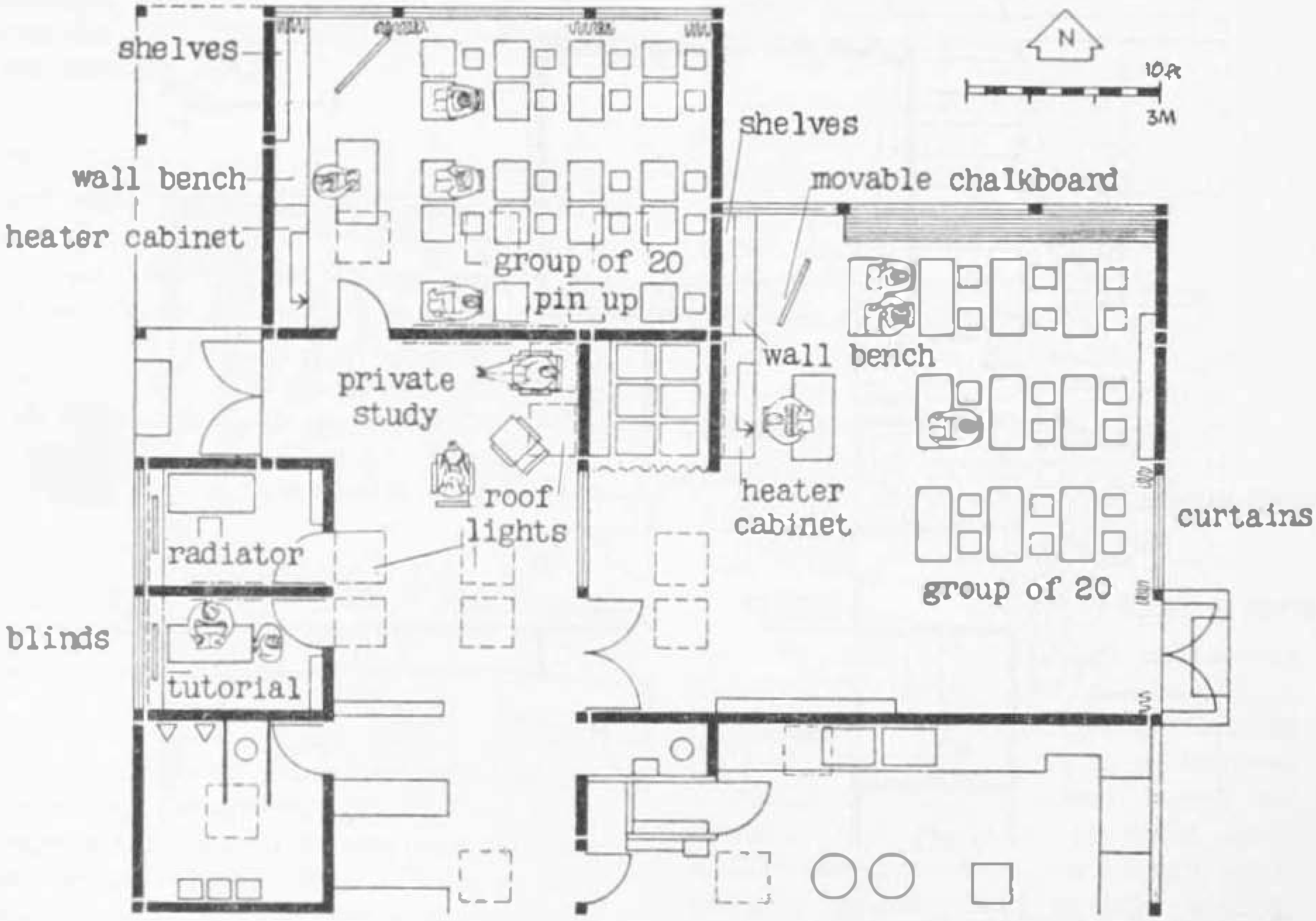


Diagram 11. HOUSE—teaching

school rooms, but the chalkboards are movable and can be stored away. During school hours, the housemaster's study may be used for tutorials, while the study bay in the house hall may be used by two or three pupils working on their own. The study bay is equipped with two hinged writing tables which fold flat against the wall when not in use, and one or two easy chairs with book rests.

82. Diagram 12 shows how the house-rooms will be used for dining by the whole of the school, pupils and staff. Each house-room can seat 128 diners in two sittings, which will allow for 100 per cent dining. Each sitting is accommodated at eight tables, each for eight diners, and will be based on family organisation, two from each table acting as servers. The tables are made up of dual teaching tables with clip-on extension tops which, when not used for dining, are stacked away in the store room. Only six extension tops are needed in each house-room. Additional chairs are taken from the store

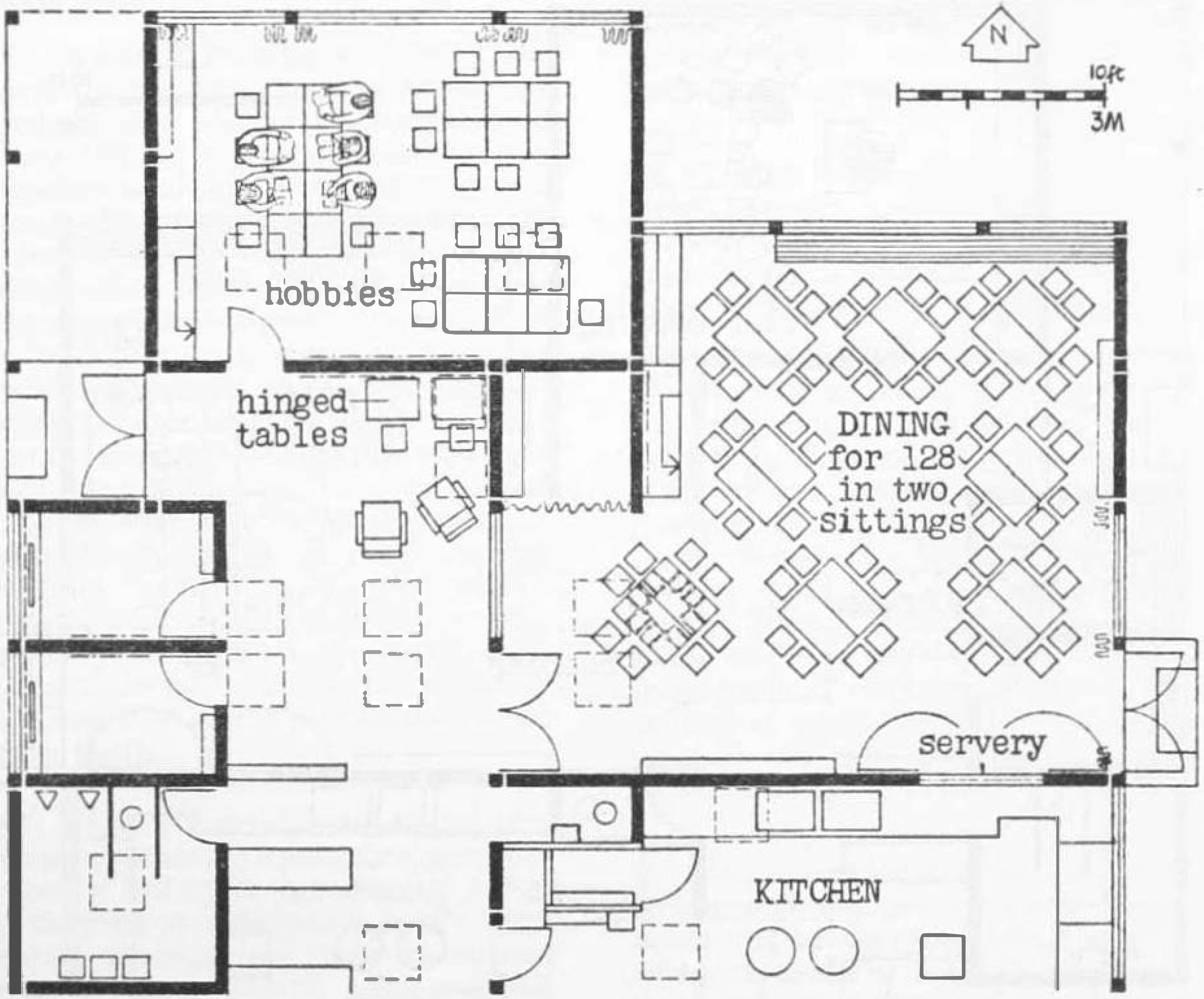


Diagram 12. HOUSE—dining

adjacent to each house-room. In order to prevent sound from the kitchen from interfering with teaching, the servery hatch has special hinged doors of heavy construction with all edges sealed with bronze strips.

83. Throughout the lunch periods, those who are not dining may use the group-room.

84. After school hours, the house may be used for a variety of activities. Diagram 13

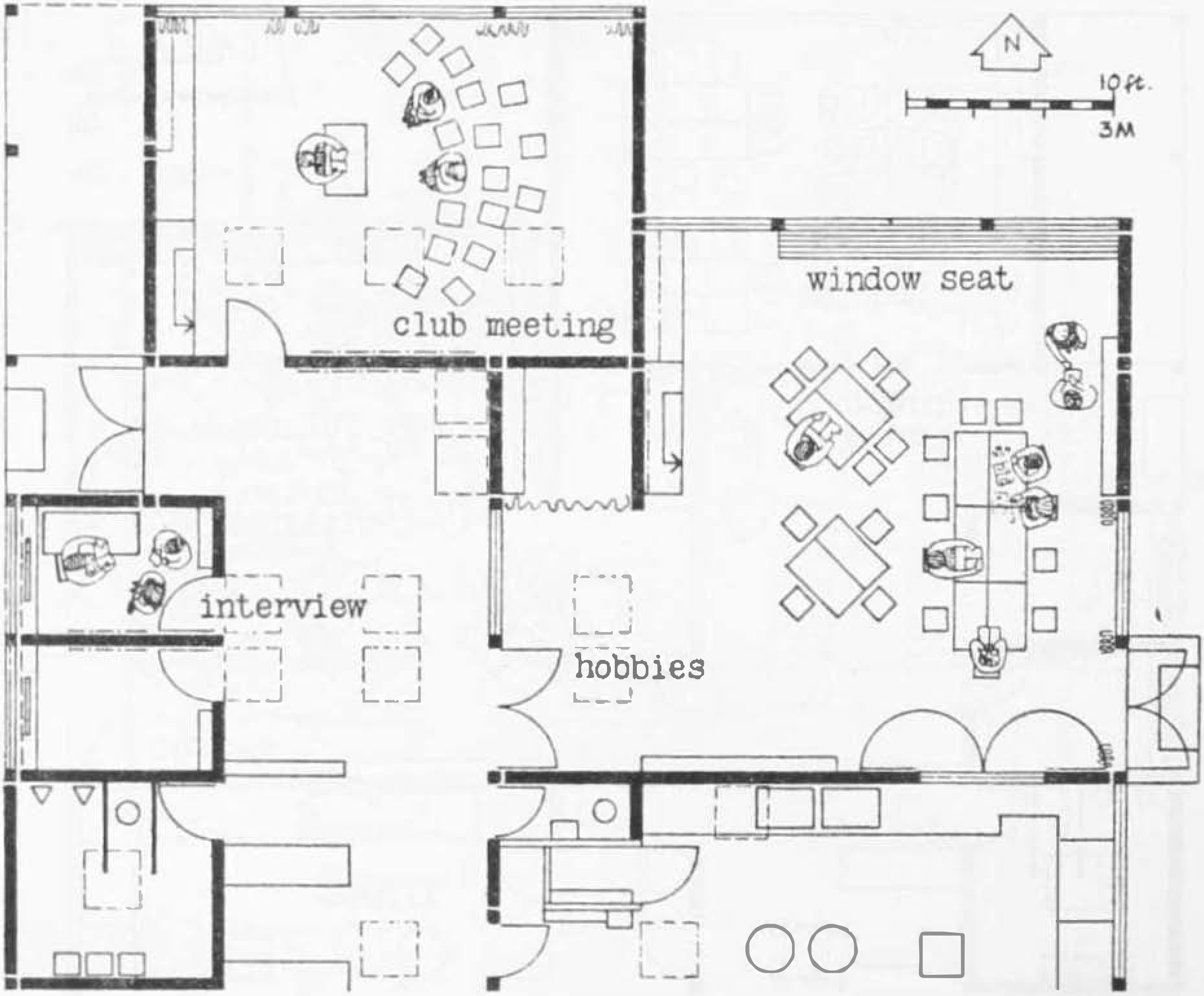


Diagram 13. HOUSE—after school activities

shows the housemaster using his study for a meeting with the parents of one of the members of his house. The group-room is arranged for a meeting, possibly of the science or literary society (in another house the group-room might be set aside for pupils wishing to do their homework at school). The house-room itself can be used as a general club-room, for table-tennis, for play rehearsals, for house meetings or, in fact, for any of the multitude of activities which make up the social life of the house or the school.

85. For a full list of furniture and equipment, see Appendix 1.

Sixth form

86. In most of the schools visited, it was usual for the sixth form to be accommodated in a number of classrooms of about 480 sq. ft. The sixth form would therefore be divided fairly arbitrarily into forms of about thirty, the division not corresponding to the teaching groups, which would usually be smaller in size. Even these teaching groups were not found to be stable units, owing to the great variety of teaching courses and the consequent cross-setting. Sometimes the sixth form prefects had a small room for their own use, perhaps a converted locker-room or large store, furnished informally with table and chairs and, possibly, having facilities for making tea and snacks. Headmasters felt it important that this kind of room should be provided in order to foster the idea of discussion and debate as an essential part of the education of the older pupils.

87. These observations led to the provision at Arnold of a sixth form common-room of 850 sq. ft. (see diagram 14). It is designed as a club-room for the older pupils, treating them more as students than as school children. Along one wall runs a long, fixed seat. There are square tables for groups of four and individual hinged writing tables. A wall-bench fitted with a sink and griller, and with cupboards above, provides the means of preparing tea and snacks. On two sides of the room there are bays of book lockers, whose internal dimensions are 30 in. by 11 in. by 9 in., sufficient in number for the whole of the sixth form.

88. The common-room opens on to a south facing terrace, which is part of the house courtyard but separated from it by being raised 4 ft. above the general level. The balustrade to this raised terrace is designed to form a continuous seat, and in addition the chairs and tables can be brought out from the common-room and placed on the terrace in fine weather.

89. Though designed primarily for informal use, the common-room may on occasion be used for special teaching purposes, e.g., a debate, or a lecture to the whole sixth form on some general subject.

90. For ordinary teaching purposes there are four rooms ranging in size between 210–310 sq. ft., suitable for groups of up to 15 students. (See diagram 7). These rooms are entirely for sixth form teaching use, although one also serves outside teaching hours as a house-group room; they are designed as annexes to the library where the sixth formers will naturally spend much of their time. Indeed as the number of books increases, those which are used only by sixth formers may well be moved into these rooms.

91. The conventional, formal classroom arrangement was not considered appropriate for the discussion group type of lesson which will be frequently adopted in the sixth form. In three of the rooms large tables are provided, which can be placed together for the whole group of students. In one of the rooms, however, there are individual tables, as it will serve as an additional private study room. Chalkboards are of the hinged and folding type, which give a writing surface of twice the wall area and which, when closed, expose a surface of pin-up board.

92. To complete this summary of the general teaching accommodation for the sixth form, reference should be made to the private study library, which is adjacent to the sixth form teaching rooms and

studies. Though not a formal teaching space where a teacher will ever take a class or group, it is an essential part of the accommodation for sixth form pupils, catering as it does for one of the principal "learning" activities which characterise their work.

93. For a full list of sixth form furniture and equipment, see Appendix 1.

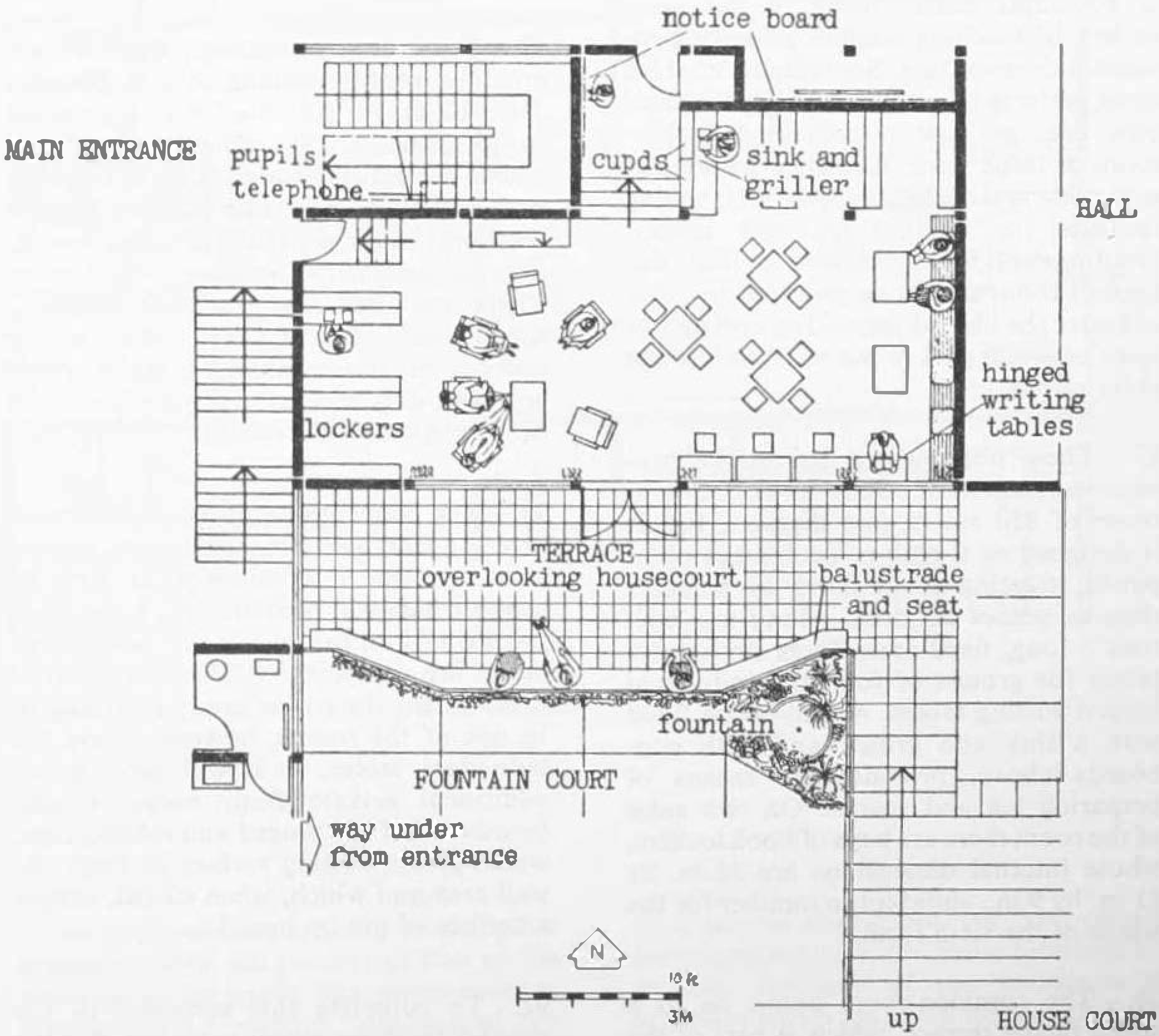


Diagram 14. SIXTH FORM COMMON ROOM
Area: 850 sq. ft.

SCIENCE ACCOMMODATION

General

94. Apart from the division of science into its constituent subjects of physics, chemistry and biology, the feature of science teaching, as practised in existing grammar schools, which had the greatest implications for the planning of new accommodation was the separation of the work into practical and theoretical studies. The theoretical work usually took the form of a talk by the teacher, using the chalkboard and, quite often, giving a practical demonstration or using visual aids, with the pupils listening, watching, asking questions and taking notes.

95. The practical work, on the other hand, was normally carried out, at least up to 'O' level, by pupils working in pairs, setting up and working experimental apparatus, taking readings and notes, with the teacher moving amongst them giving help and guidance. After 'O' level, students were more frequently seen working on their own at theoretical and practical work. Two or three groups might sometimes use one laboratory at the same time, with only very general supervision by a teacher.

96. While practical work was always, of necessity, carried out in a laboratory, a variety of accommodation was seen in use for the theoretical studies. Some schools had a lecture room with tiered seating, others had a science classroom, with a sink and other services in a wall-bench near a teacher's table. In many cases, of course, the laboratory itself was used. Another arrangement, often discussed but not actually seen, is to have a lecture bay at one end of the laboratory, or in a space between two laboratories.

97. All these arrangements have their advantages and disadvantages. The tiered lecture-room, and its alternative the science classroom, provide ideal conditions for watching a demonstration and for taking notes at the same time—the pupils being seated at tables or writing surfaces designed primarily for that purpose, and in a good position to see the demonstration bench. But, assuming the laboratories are in more or less constant use, the provision of this kind of room would imply that a whole period would be spent there, and most science teachers considered this amount of theoretical work at one time to be inappropriate for all but the most senior pupils.

98. To use the laboratory for theoretical work avoids this difficulty, the teacher being able to switch to practical work, and back again, as occasion demands. But in a laboratory designed primarily for practical work, with good space between benches, some pupils must necessarily be badly placed for watching the teacher's demonstration. The teacher either accepts this disadvantage or collects the pupils in a group near the demonstration bench, in which case it is difficult for them to take notes. Another disadvantage is that laboratory benches, being designed for pupils standing up to do their practical work, are unsuitable, both in height and knee-room, for writing; laboratory stools, also, are not helpful in this respect.

99. The third arrangement, the inclusion of a lecture bay as part of the laboratory, would obviate all the disadvantages of the

other two arrangements and should therefore provide the ideal solution—good vision and suitable seating for demonstrations combined with practical facilities which are adjacent and available at any time—but it obviously requires more space and this has to be considered in relation to the needs of the school as a whole.

100. At Arnold it was decided that the client's brief would best be met by designing the laboratories as practical rooms and by making provision for theoretical work in a tiered lecture demonstration room.

Provision at Arnold

101. The accommodation provided for science at Arnold is set out in Table 3 below.

102. The science accommodation is in a three-storey block approached from the school through a glazed corridor, which forms one side of a science courtyard. As designed, this corridor is adequate only for circulation. An additional module in width would have increased the value of this space considerably by making it possible to create small experimental or exhibition bays, possibly associated with the courtyard. But there is, of course, a limit to what can be added in this way. There is, however, at the entrance to the block, an exhibition space, with a small study bay for about six pupils, which can be used either for a small class or for private study.

103. On the ground floor of the block (see diagram 15) are the two chemistry laboratories and the biology laboratory. The latter opens on to the science courtyard which contains a greenhouse, experimental planting beds and a pond. On the first floor are the physics, mathematics and general science laboratories and, on the top floor, the lecture demonstration room and the geography, technical drawing and commerce rooms. A small service lift connects the preparation rooms on each floor, so that equipment can easily be taken up to the lecture demonstration room.

104. With the exception of the general science laboratory, the layout of the

Table 3. Science Accommodation

Room	Area sq. ft.	User
General science lab.	901	Lower school groups of 30
Physics lab.	673	Middle school groups of 20
Chemistry lab.	673	,, ,, ,, ,,
Biology lab.	673	,, ,, ,, ,, and sixth form max. groups of 20
Advanced physics lab.	673	Sixth form max. groups of 20
Advanced chemistry lab.	673	,, ,, ,, ,,
Mathematics lab.	506	General, groups—max. 20
Lecture demonstration room	673	General, larger groups
4 Preparation rooms, each 200 (including storage) attached to biology, physics, chemistry and lecture demonstration rooms.		
Optics room	154	
Balance room	120	

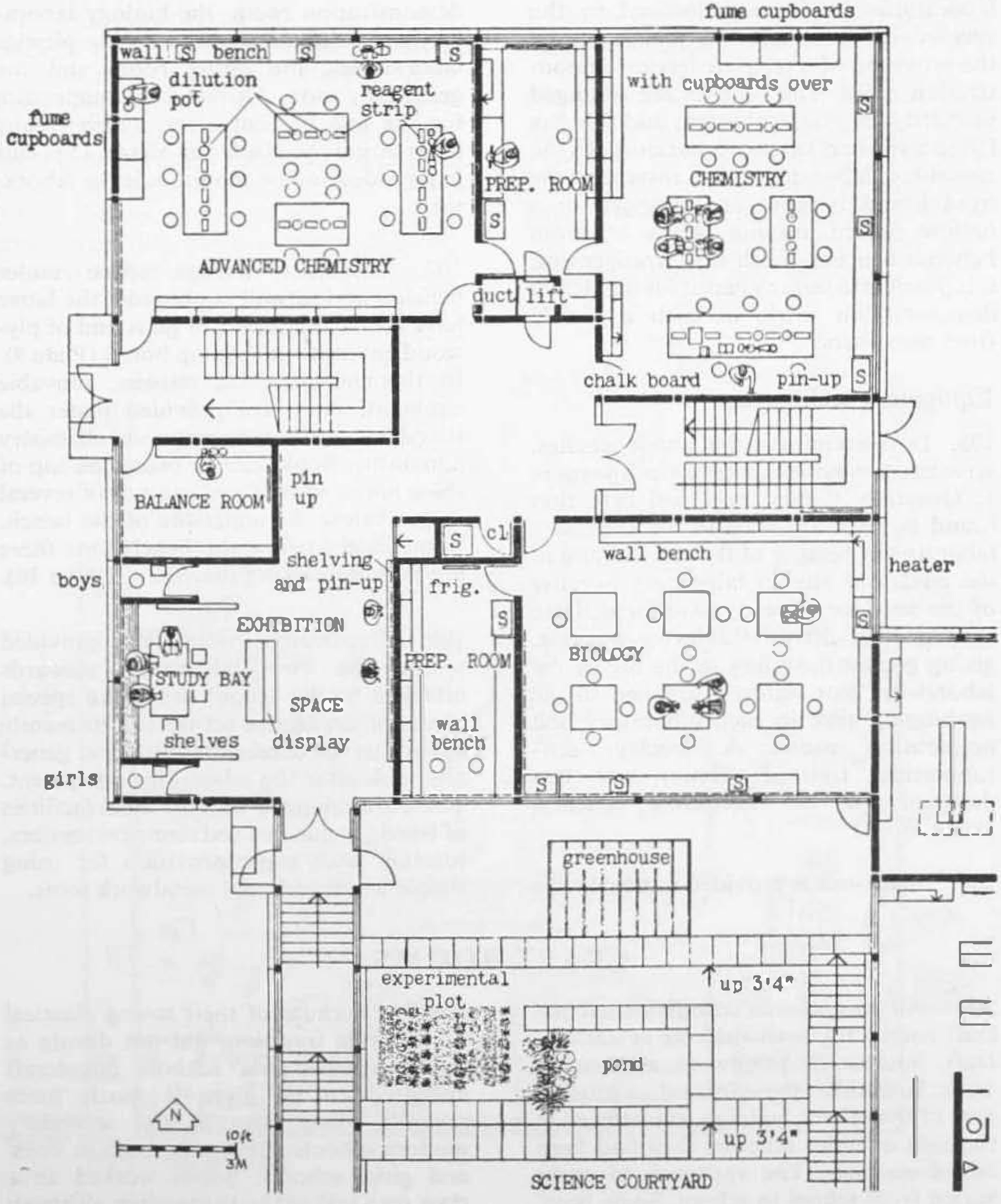


Diagram 15. SCIENCE DEPARTMENT—ground floor
For areas see Table 3

laboratories has been influenced by the smaller size of the teaching groups and by the provision of a separate lecture demonstration room. The benches are arranged primarily for practical work, and this has led to a smaller, squarer laboratory. In the chemistry laboratory, for instance, the fixed island benches are arranged in a hollow square, leaving plenty of room between benches. With this arrangement, it is possible to use any bench for incidental demonstration work, as each is visible from the others.

Equipment and storage

105. Detailed information about benches, services, storage, etc., is given in Appendix 1. Generally it may be noted here that island benches are fixed in the chemistry laboratories because of the services and in the advanced physics laboratory because of the need for a steady base for delicate readings. Elsewhere the tables are movable, giving greater flexibility in the use of the laboratory. Hot water is supplied to the washing-up sink in each laboratory and preparation room. A fireclay, self-supporting, trapped dilution pot was designed for the chemistry benches. (Plate 6).

106. Black-out is provided in the lecture demonstration room, the biology laboratory and its preparation room, the physics laboratories, the optics room and the geography room. Extract fans compensate for the loss of ventilation which results from fitting the black-out blinds. Dim-out is provided in the general science laboratory.

107. There is storage space under benches and in wall cupboards; the latter have doors alternately of glass and of plywood covered with pin-up board (Plate 9). In the chemistry laboratories, movable cupboard units are provided under the island benches for storing pupils' chemistry apparatus. Books can be placed on top of these units, where there is a gap of several inches below the underside of the bench. Immediately below the bench tops there are pull-out writing shelves. (Plate 10).

108. Preparation rooms are provided where the two laboratory stewards attached to the school can make special pieces of apparatus, set up and dismantle apparatus for demonstrations, and generally look after the laboratory equipment. These are equipped with the usual facilities of bench, water, gas and electrical services, together with some provision for using simple woodwork and metalwork tools.

CRAFT ROOMS

109. All the grammar schools visited had craft rooms for such subjects as art and craft, housecraft, woodwork and metalwork. Sometimes these formed an integral part of the school building, sometimes, in the case of older schools, they had been added on later. The approach to crafts varied from school to school. Some boys' schools, particularly those with a technical bias or stream, ran very detailed courses in both woodwork and metalwork; others, possibly because of their strong classical or scientific tradition, did not devote as much time. In girls' schools, housecraft appeared to be given a much more scientific basis than in the secondary modern schools. Generally, both in boys' and girls' schools, pupils worked as a class on a task set by the teacher, although individual pupils were occasionally found engaged on a model or pieces of apparatus of their own.

110. The intention of the brief for the practical rooms at Arnold was to enable pupils to make a selection of crafts, as of other subjects comprising the course they would follow. For instance, some pupils might consider art, woodwork or domestic science as subjects to be offered in the G.C.E. Others, not so drawn to making things with their hands, might prefer to broaden their scientific or language courses by studying the history of painting, of sculpture or of pottery.

111. On the subject of craft teaching, local employers, who were among those consulted, thought that thorough basic teaching in science, mathematics and English coupled with a recognition of the function and potentialities of tools and materials, rather than the acquisition of

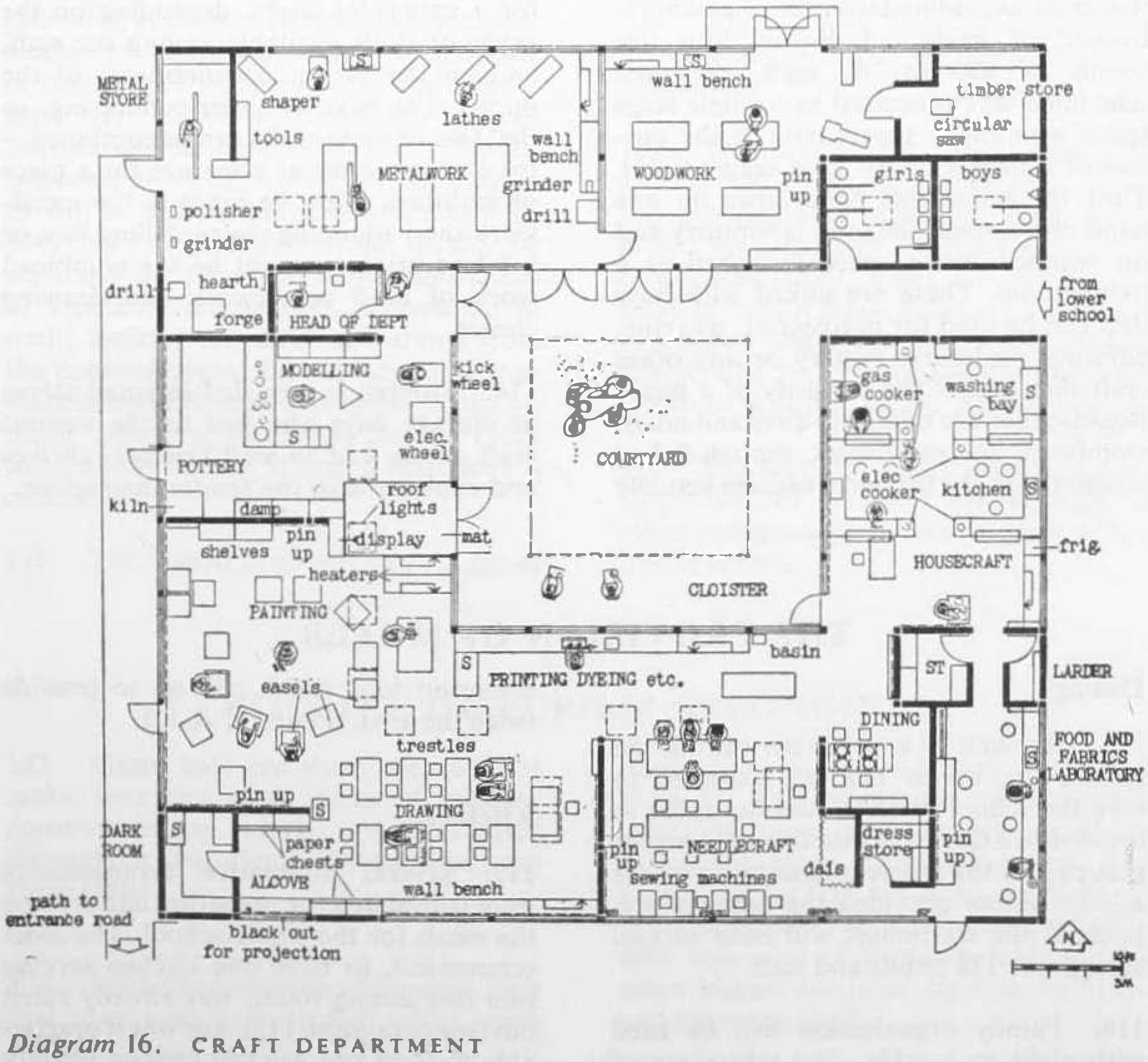


Diagram 16. CRAFT DEPARTMENT

Total area: 4,432 sq. ft.

manual skills, would provide the most promising background for employment in the higher ranks of industry. They pointed out that the will to work and love of the work undertaken were qualities for which they looked when appointing their staff. Given these, they could quickly train intelligent recruits in the technical skills required for workshop practice.

112. These were among the opinions that suggested the somewhat novel design of the craft accommodation in the school. Instead of being sub-divided into five rooms of 850 sq. ft. each, the area scheduled was conceived as a single large space with zones appropriate to the pursuit of different crafts. (See diagram 16). Thus the housecraft zone flows on one hand into a small dietetics laboratory and on another into a space furnished as a living room. These are linked with bays that can be used for needlecraft, weaving, painting, sculpture, pottery or any other craft that excites the curiosity of a pupil. Because they are relatively dirty and noisy, woodwork and metalwork, though linked visually with the former areas, are actually divided from them by glazed partitions. The whole group of spaces is arranged in the form of a hollow square and the central courtyard provides at once direct access to any particular craft and additional space where on suitable occasions work can be taken into the open air.

113. Some of the bays, because of their special fixed equipment, are limited to particular crafts. Others, equipped with basic storage and services, may be used for a variety of crafts, depending on the range of skills available among the staff, and on the various requirements of the pupils. The bays are inter-connecting, so that two or more crafts can be combined—for instance a metal armature for a piece of sculpture might be made in the metalwork shop adjoining the modelling bay, or a fabric printing might be the combined work of both needlework and drawing classes.

114. Storage is provided in small stores or storage bays attached to the various craft areas, and in wall-benches, shelves and cupboards in the spaces themselves.

THE PROVISION OF MEALS

Dining

115. Between 90 and 100 per cent of the pupils, i.e., up to 720, are expected to take the school meal. It was desirable to break down this large number into smaller groups and the house organisation of the middle school provided the opportunity. Each of the six houses will cater in two sittings for 128 pupils and staff.

116. Family organisation will be used with eight to a table. The tables are of the usual dual teaching type, but they have extension tops which clip on to provide twice the area. (Plates 11 & 12).

Kitchen

117. Several alternative arrangements were considered for preparing and serving the meals for the whole school. The most economical, to have one kitchen serving into one dining room, was already ruled out (see paragraph 115), nor was it practicable to have one kitchen serving directly into six dining rooms. The possibility of

having three separate kitchens serving pairs of houses was considered but this would have meant a long peripheral service road.

118. This left two solutions for final consideration. The first was to have a central kitchen serving the six dining rooms by means of heated trolleys, the second, to have a central food store and vegetable preparations area supplying the uncooked food to each of three kitchens. The latter alternative was preferred for the following reasons: (1) direct service from kitchen to dining rooms ensures that none of the heat or palatability of the meal is lost; (2) closer relationship between kitchen and house staff should make for smoother running; (3) a 250 meal kitchen should be more manageable than one for 750; (4) its domestic scale should be attractive to kitchen staff; (5) centralisation of vegetable preparation, economical in itself, isolates the dirty operations from the cooking areas; (6) the cost of equipment is lower, heated trolleys in particular being expensive (although on the other hand about 400 sq. ft. more floor area is needed).

119. The central store will contain about three weeks supplies. It will be staffed by a supervisor-storekeeper, responsible for ordering all supplies, checking the deliveries, issuing food daily to the three kitchens and carrying out all the general clerical work of the meals service. She will be helped by one or two assistants either permanently attached to the central store or drawn from the kitchens. The menus for each kitchen, possibly different from one another, will be the responsibility of the cook-supervisor in each kitchen, who will order supplies daily from the central store. For ease of communication, the kitchens are linked to the central store by telephone.

120. The three kitchens, each capable of serving 250 meals, are based, except for the storage and vegetable preparation areas, on BUILDING BULLETIN No. 11* recommendations. There is in addition a small larder for those goods which are not completely used up in one day, and a refrigerator for the occasions when meat has to be prepared on the previous day.

121. The serveries also follow BUILDING BULLETIN No. 11, and are planned to allow independent service to each of the dining rooms.

STORAGE OF PUPILS' BELONGINGS

122. Coats, hats and shoes are stored in racks near the small units of sanitary accommodation which are distributed throughout the school. Plate 4 illustrates these racks.

123. With the exception of those in their first year who have locker tables, each pupil has a locker for storing books (see Plate 8). The dimensions of the locker were determined from a survey carried out in some existing grammar schools. The sixth form lockers are 30 in. by 9 in. by 11 in. and have two shelves, and space to take one row of foolscap folders. The other lockers are 16 in. by 9 in. by 11 in. and have one shelf.

*Ministry of Education Building Bulletin No. 11—The Design of School Kitchens (H.M.S.O. out of print.)

124. Instead of the usual storage for gym kit, the experiment is being tried of having a laundry. The extra cost of running this system has, of course, to be weighed up carefully—but against this cost can be placed some considerable advantages. Kit, once used, is returned directly to the laundry, instead of lying dirty in a locker or satchel before being taken home for washing. There is a saving of space, but the consequent saving in cost is almost outweighed by the cost of the equipment. (See Appendix 2).

125. The gym kit is supplied by the Local Education Authority in sufficient numbers and sizes to cater for the whole school, and is stored on shelves separating the laundry from the corridor which leads to the changing rooms and the gymnasium. Bins are supplied for used kit and towels.

126. The laundry has three machines, a washing machine, a hydro-extractor and a drying tumbler. In order to sterilise the garment, the temperature of the water in the washing machine is raised to 200°F. or more. After washing, the clothing goes first into the hydro-extractor, which removes some of the water by centrifugal force, and then into the drying tumbler which completes the operation by heat and movement. This method makes ironing unnecessary.

127. The laundry equipment is similar to that used in small commercial laundries and hotels, but as it is not economical or practical to use steam in a school heating system, machines were chosen which boost water temperatures and provide heat for drying by means of electricity.

ADMINISTRATION

128. The information given in BUILDING BULLETIN NO. 2* on the accommodation required for the teaching staff applies generally to grammar schools also. Three additional points should be noted:—

(1) as grammar schools tend to be large and complex, part of the staff accommodation may usefully be provided in the form of small studies associated both with the social spaces (for staff who as form or house masters are responsible for the general well-being of a group of pupils) and in parts of the building which house departments such as science, music and crafts (for heads of departments);

(2) although one main common room is generally preferred, a small writing room is a useful adjunct for teachers who wish to work quietly during break or the lunch hour. During school hours, the main common room itself is available for this purpose;

(3) advice on careers is usually made available to pupils and parents either by a member of the staff or by the Youth Employment Officer. A separate room is not essential for these meetings—the medical inspection room or one of the small studies could be used. It is, however, useful to have a pin-up board, on which information about careers can be posted, put up in a part of the school used by the older pupils.

129. The information in BUILDING BULLETIN NO. 2 on other administrative rooms and stores is also relevant to

*Ministry of Education Building Bulletin No. 2—New Secondary Schools (H.M.S.O. out of print) grammar schools, though storage for a far greater number of sets of text books is required. At Arnold, provision has been made for 5,000 books (additional to the 7,000 books in the library). Storage can, of course, be far more compactly arranged than in a library.

THE SITE

Playing fields

130. The site is 34½ acres in extent (see plan) and will accommodate, in addition to the grammar school, and its playing fields, a two form entry girls' secondary modern school and its playing fields, and the playing fields for 200 boys from another secondary modern school.

131. It was decided to construct the playing fields for all three schools together under one contract. The grammar school itself has two rugby pitches, two hockey pitches, one cricket square, three jumping pits and seven tennis courts, and also shares with the other schools a four-lane cinder running track. The tennis courts (six forming part of the statutory paved area, the seventh is in the covered athletics shed) were provided from the nett cost of the grammar school.

132. In order to have the playing fields available by the time the school opened, their construction was started, under a separate contract, in advance of the main building contract. (See Table 4). This also allowed the best to be made of the natural seasonal processes; for instance, when the major earth moving had been completed the pitches were left fallow throughout one winter in order to clean the land.

133. The steep slope of the land presented considerable difficulty in the construction of the playing fields, and required the formation of terraces with banks ranging in height from 8 ft. to 17ft. The most gradual slope possible, if too much land was not to be used up, was 22½°. Although a slope of this kind is not difficult to mow where the bank is small, the banks at Arnold were so large that tractors would have been in danger of slipping and overturning. To cut down the mowing as much as possible, therefore, the banks were sown with meadow grasses and wild flowers and will only need to be scythed once a year. The appearance of these banks, with the colour and texture of the flowers punctuated by trees, should provide a more natural and interesting appearance than the normal expanse of close-cropped sward.

134. The seeding specification for the pitches generally was:

1 cwt. per acre, composed of:
- 35 lbs. S.23 perennial rye-grass,
- 14 lbs. crested dog's tail,
- 7 lbs. rough stalked meadow grass,
- 49 lbs. chewings fescue,
- 7 lbs. New Zealand browntop.

135. Seeding trials have been carried out on four areas which will be subjected to equal use:—

N. W. quarter 60 per cent S.23
- 10 ,, ,, crested dog's tail
- 10 ,, ,, chewings fescue
- 10 ,, ,, creeping red fescue
- 10 ,, ,, New Zealand browntop

at one cwt. per acre.

S.W. quarter As in N.W. quarter but 1½ cwts. per acre.

N.E. quarter As in paragraph 134.

S.E. quarter As in N.E. quarter but 1½ cwts. per acre.

136. Twelve months after sowing, no differences between the areas were visible, but the full value of the experiment will not be known for several years.

Landscape

137. The site is a fine one, with good prospects ranging from the comparatively rural and unspoilt Mapperley Ridge towards the east to the outskirts of Nottingham bounded by low hills to the south-west. Rather in the shape of a tilted saucer, it can be seen from afar and the school, with its surrounding acres, will become a focal point in the landscape, with the grand scale of the embankments and cuttings to the playing fields echoing the terraces of the school itself.

138. Horizontal and vertical dimensions are so great (there is a difference in level of 90 ft. from north-east to south-west) that only with considerable numbers of forest trees could it be hoped to provide points of reference for scale and distance. The position of belts and clumps of trees was determined, therefore, both by their basic function as wind breaks and by this need for visual punctuation. For complete list of planting materials see Appendix 4.

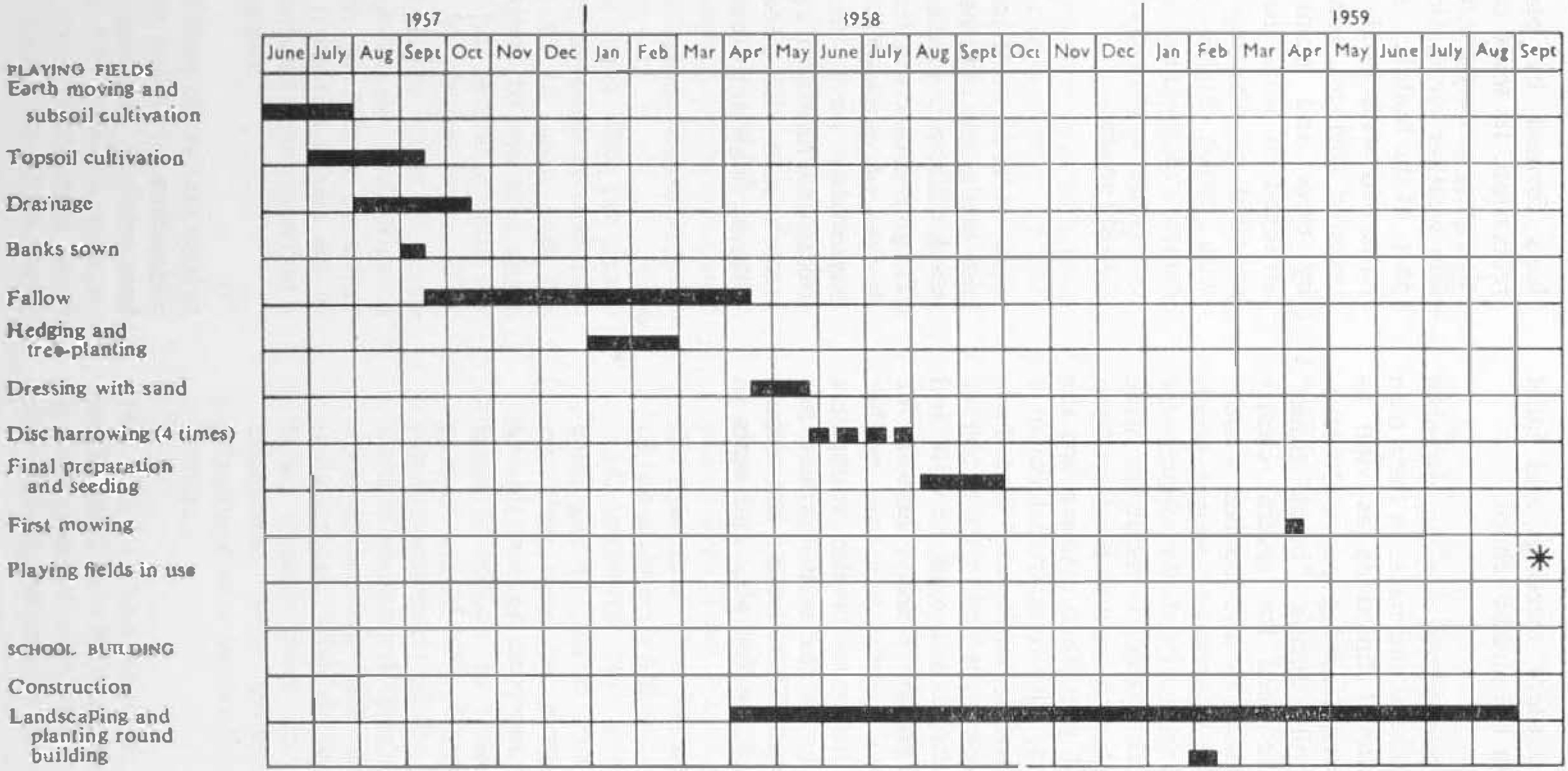
139. Normally there are good reasons for not having trees on, or adjacent to, pitches—they reduce the limits within which the pitches can be moved, they provide unwanted shade and drip on the grass, and they make mowing difficult. At Arnold, with the planting of trees on, and immediately adjacent to, the scythed banks, these objections were overcome, and the usual bareness of playing fields avoided. For these areas sycamore, Norway maple and ash were chosen.

140. Nearer the school, smaller groups of trees and isolated specimens of rather more exotic type have been planted, in order to create a more domestic feeling and also to provide useful subjects for botanical study. On most of the embankments and cuttings around the school building low ground-covering shrubs were planted; those which are to be used as outdoor teaching spaces have, however, been grassed.

141. The main approach to the school is bounded on one side by a broad bank of lavender and on the other by a row of red twigged limes which, by their regularity, delineate the division between an approach road and car-park. The approach terminates at higher level in the entrance court, where small flourishing trees (snowy mespilus) contrast with the larger limes and introduce a smaller scale. Here also the areas between the paved traffic routes to the craft block and the lower school have been planted with low spreading shrubs through which naturalised bulbs flower in the spring. Paving is generally direct from point to point but thorny shrubs have been planted to discourage short-cutting at certain points.

142. The main approach leads at the lower level into a small court with a fountain, and climbing plants are used to cover the retaining walls to the sixth form terrace. This space then opens out into the central court, which is designed as a

Table 4. Relationship between school and playing fields construction periods



centre for outdoor meetings and quiet recreation for the middle school.

143. The courtyards are an essential part of the school and have, in their own way, educational functions as vital as those of internal teaching spaces. Observation of pupils during "break times" indicated the need for several clearly differentiated areas and courts. Firstly, there are the boisterous younger pupils who need unconstricted play space—for them several artificial mounds, wide flights of steps and treed slopes have been designed. At the other extreme are the sixth formers, who tend to behave in a more purposeful, adult way and have therefore been provided with a terrace where they can sit and read, or walk and talk in small groups. Thirdly, there are the middle school pupils, who are neither quite so boisterous as the youngsters nor so sedate as the sixth formers but border on both. These have a housecourt with open paving for play and seats in bays formed by planting for quieter relaxation. In some cases the courtyards also serve as outdoor teaching spaces or as fine weather circulation between various parts of the building. Paving is sometimes patterned with brick squares and other textured surfaces, sometimes punctuated by trees and plant tubs, sometimes arranged in small bays with seats surrounded by planting. All this, together with broad flights of steps, terraces, ramps and retaining walls, is designed to contribute to the richness and value of the outside spaces.

144. A final word may be added about the landscape treatment of the athletics shed, which provided a particular problem. To give protection from the wind, wide hedges of quick-growing hawthorn and myrobalan have been provided, with occasional hawthorn trees to ease this long screen into the broader landscape of playing fields and forest trees.

11. STRUCTURE AND SERVICES

INTRODUCTION

145. The Ministry's interest in the development of prefabricated systems of construction for school building has not been due to any desire for prefabrication for its own sake, nor has there been the expectation of any saving of money compared with traditional forms of construction. The fact simply is that as the series of large building programmes of recent years got under way it became clear that the labour force available would never meet all the increased commitments, certainly not in time. Some areas were, of course, more fortunate than others in this respect, but there were few which did not suffer to some extent from the shortage of bricklayers, plasterers and labourers, and in many the situation was desperate.

146. It was thus clear that for many years prefabricated systems of construction would have to be used and the Ministry was anxious to see that there should be not one but several systems for local authorities to choose from. The school at Arnold is the latest of seven development projects in prefabricated construction, each of which is either entirely different from the others or, at least, contains significant changes within a previously tried system.

147. Before describing the system used at Arnold it may be useful to summarise here the advantages of prefabricated systems generally, for, while it may be true that many local authorities were forced by circumstances to adopt them, many by now continue to use them because of their inherent merits. These may be stated as:

(1) speed of erection;

(2) ease of planning: the structural design work is "built-in" to the system and the design limitations, such as they are, are simple and easily mastered. Planning is freed from the load-bearing wall and by its nature the system may contribute much, especially by way of flexibility, to the plan:

(3) simplification of drawing: standard component drawings are supplied by the manufacturer and working drawings are consequently greatly simplified even when a system is used for the first time. This facilitates the work of the architect's office;

(4) improved cost control: with a catalogue of priced components cost checking may be more precise. A greater use of component scheduling tends to reduce the time required for preparation of bills of quantities. Also, rapid assessments of the cost implications of planning decisions are possible;

(5) authorities with small building programmes, who do not possess a large enough staff to prepare the occasional large project, can take advantage of a thoroughly worked out system.

148. So far, the advantages to the clients and his staff have been considered. But the use of "systems" offers advantages also to the building and manufacturing industries.

Among these are:

(1) ease of control: factory conditions promote the development of highly skilled teams of technicians. Thus full advantage may be taken of flow production techniques, including scientific control, testing, the economic use of comparatively intricate and expensive machinery, the use of sometimes unconventional techniques and accurate costing. This means a more efficient and logical use of materials and manpower, and should lead to better commercial results;

(2) speed of erection: the contractor can keep skilled erection teams together; teams which come on to the site to do a single specific job are organised and "bonused" accordingly.

ORGANISATION AND CONTROL DURING THE DEVELOPMENT PERIOD

149. Development work was placed in the hands of a group consisting of principals of the contractor's research and development department, a senior agent from the contracting side of the same firm, the structural engineer (who was in this case employed by the contractor) and an executive architect from the Ministry. Although from time to time they met the directors of the firm and the heads of the Ministry's Architects and Building Branch to discuss the broader implications of their work, all the members of this development team were empowered to take decisions on policy, as well as on purely technical matters, as their work progressed. There is no doubt that the successful organisation and control of the project can be largely attributed to this fact.

150. Second only in importance was the availability of the contractor's highly skilled and experienced research and development organisation, which could cast and test all components as and when the design team required. This was of fundamental importance, as the design team were not engaged on modifying an existing structural system but were designing a completely new system from the beginning. The technique of pre-stressed and post-tensioned concrete is still comparatively new and few, if any, design rules exist which could be applied to the particular form of structure which was being developed. The method of design therefore had to be largely empirical and each component had to be tested and the results used by the team in the task of refining the next stage of the design. This was a continuous process and involved an extensive programme of detailed tests in the structures laboratory together with a continuous study and evaluation of the results obtained by the engineers and the design team as a whole.

151. Of great importance, too, was the close day-to-day liaison with the quantity surveyors, who considered the cost of each component as it took shape under the pressure of structural, contractual and architectural requirements. This cost process is described in more detail in Section III.

152. When the design of the structural members and screens was nearing completion a small "mock-up" was designed which included as many different junctions, changes of level, etc., as possible.

The aim was to provide practical experience of various aspects of the system before setting out on final production runs. The aspects were:

(1) erection procedure, and all the problems involved in "fitting the bits together";

(2) tolerances, both between particular parts of the structure and between the structure and the screens and services;

(3) detailing: the possible refining of junctions, fixings, etc.;

(4) training of the erection team.

153. In the event, the mock-up was not needed, because the contractor decided to use the system to build a two-storey extension at his Research and Development Centre. This gave the development team all the opportunity they needed of observing and refining their design, while at the same time the erection team which was to work on the school was given useful practice in technique.

154. Ideally, responsibility for the manufacture of all components of the system would have been in the hands of the sponsor, to ensure complete control. In fact, however, the sponsor decided to put all concrete components out to tender. This did not, in practice, prove to be a drawback since both the sponsor and the engineer had already applied their wide experience to the detailed design of each component, so that, when a manufacturer had been selected, he had virtually no comments or improvements to suggest.

155. The story of how these interested parties worked together is, therefore, very largely the story of how they collectively developed the structural components, with pre-determined cost targets in mind. Some of these targets proved to be too high, others had to be raised, but it was shown that it was possible to make adjustments as the job proceeded, and, in the end, this form of financial discipline justified itself when the project as a whole, and the components of the superstructure, all came out on tender within the planned cost.

STRUCTURE

General description

156. The structure consists of pre-cast concrete components, some of which are pre-tensioned and some post-tensioned. The dimensions were chosen to allow freedom of planning on a 3 ft. 4 in. square grid with a 10 in. vertical grid—these dimensions being subject to certain maximum spans and heights. It is suitable for building up to four storeys. (See diagrams 17 and 18).

157. Flexibility and location of all elements is made possible by the careful profiling of structural parts, and this also allows the design and fixing of these elements to be greatly simplified.

158. Freedom for the passage of services is maintained both horizontally through the ceiling space and vertically through the standard service ducts in partitions.

The brief

159. A brief, setting out the structural and dimensional requirements which the system would have to satisfy, was first drawn up. While it did not postulate a system profoundly different from several others at present available, it is perhaps

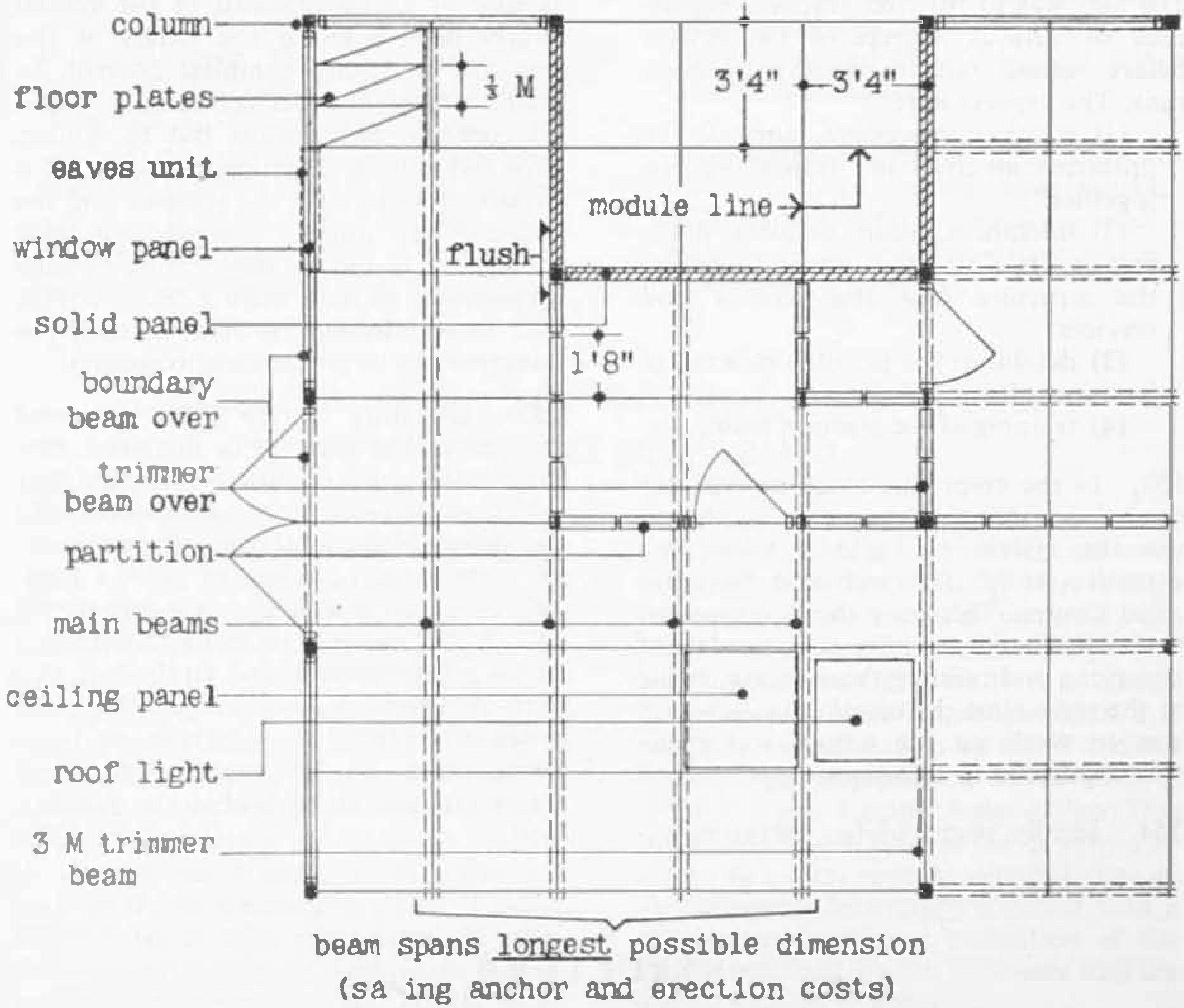


Diagram 17. RELATION OF COMPONENTS TO HORIZONTAL MODULE

worth quoting since it provides a useful yardstick for comparisons with other systems.

160. Within the over-riding requirement that it should be competitive with other systems, in speed of construction, and with both these and conventional methods in the matter of cost, the system was required to:

(1) exploit the techniques of pre-stressing to the full in order to economise in the consumption of steel and to achieve the utmost lightness and elegance of construction;

(2) be suitable for school construction up to four storeys;

(3) be an open frame, i.e. not relying on load-bearing walls;

(4) allow 3 ft. 4 in.* planning flexibility in both directions and allow internal partitions to be placed at 3 ft. 4 in. intervals in both directions;

(5) allow changes of ceiling heights,

*All the modular and sub-modular dimensions given are nominal.

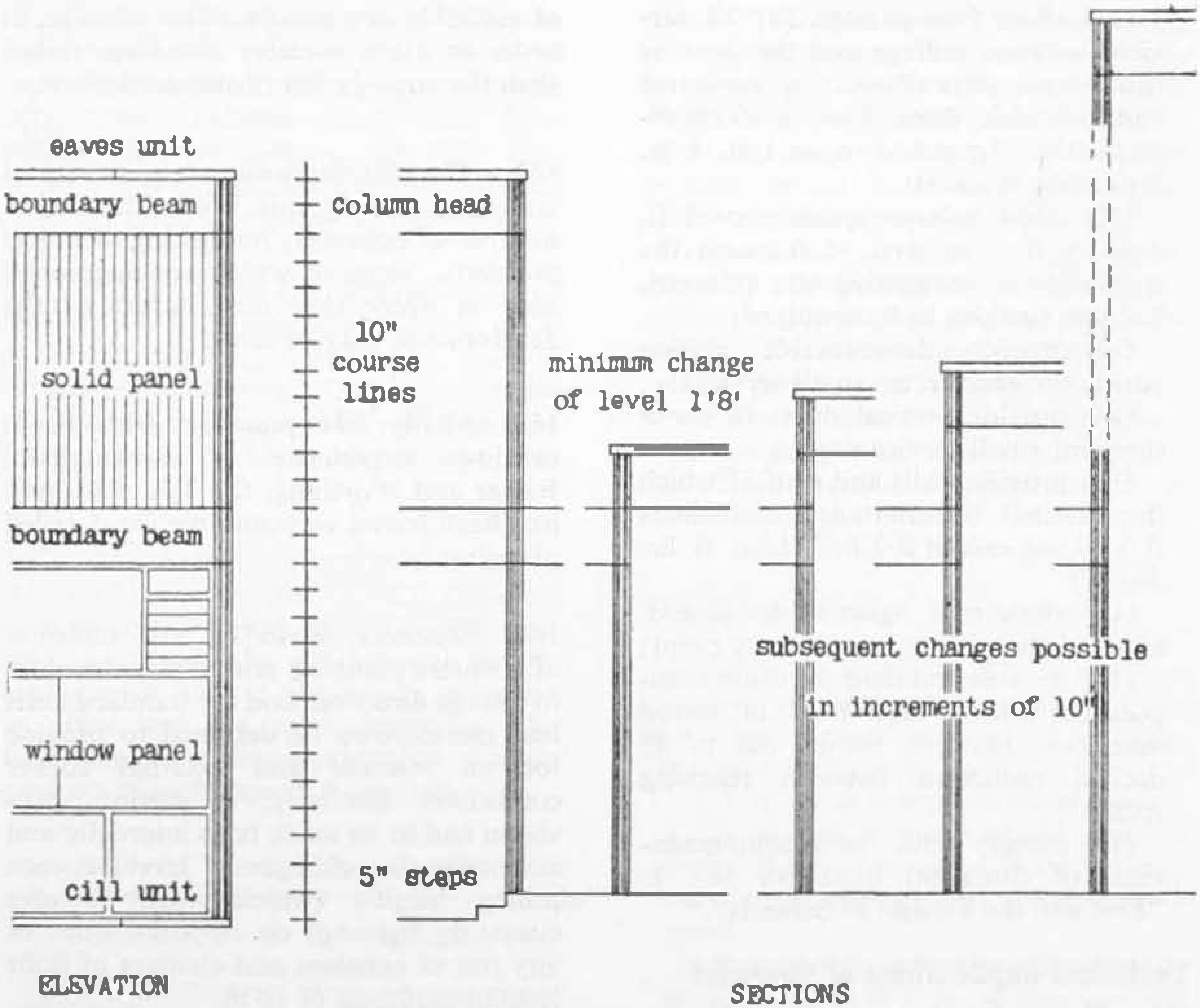


Diagram 18. VERTICAL MODULE AND CHANGES OF LEVEL

change of floor level, junctions and clerestory windows all in 10 in. increments (using standard components);

(6) permit free spans of up to 33 ft. 4 in. for floors and 46 ft. 8 in. for roofs (including halls and gymnasiums) using the same range of components—neither of these maximum spans to be limited by a maximum dimension in the other direction;

(7) consist of pre-cast components of such a size and weight that they could easily be handled by one or two men or a light mobile crane—all units to be as large as possible within these terms in order to reduce site jointing to a minimum;

(8) provide a range of light-weight cladding components with the use of concrete reduced to a structural necessity;

(9) provide a full and standard range of windows, doors and top lights, which (as with the cladding) would be dimensioned so as to eliminate special conditions at internal or external corners;

(10) be erected without the use of scaffolding;

(11) allow free passage for all services between ceilings and the floor or roof above, thus eliminating expensive and inflexible floor ducts and crawlways (this dimension to be 1 ft. 8 in. regardless of span);

(12) allow column spacings of 3 ft. 4 in., 6 ft. 8 in. and 10 ft., with the possibility of staggering the columns. Column sections to be standard;

(13) provide demountable ceiling panels for easy access to all services;

(14) provide vertical ducts in partitions for small service drops;

(15) provide walls and roof of which the thermal transmittance coefficients (U) do not exceed 0·2 B.T.U./sq. ft. hr. deg. F;

(16) allow roof lights to be placed, either singly or in groups, at any point;

(17) provide standard partition components with a high level of sound insulation between rooms (40 to 45 decibel reduction between teaching spaces);

(18) comply with the recommendations of BUILDING BULLETIN NO. 7: "Fire and the Design of Schools".*

Technical implications of the brief

161. The wider aims were, on the one hand, to exploit industrial resources and available materials, to use the best industrial techniques, and to achieve economy in production, materials and site labour, while, on the other hand, always preserving the freedom in planning which the educational requirements and the nature of the site might demand. The plan of the Arnold school, which was designed as the system was being developed, called for considerable flexibility and so tested the system very fully. The aim, therefore, was to produce a system with as few standard parts as possible but yet capable of assembly in a great number of ways, in order to allow creative planning, rather than the strait-jacket of standard plans.

162. The development of a structural system to satisfy this brief threw up a number of extremely interesting technical problems, some of which are mentioned here in order that the context of the development may be clear.

163. Firstly, *the planning grid*. From previous experience at Wokingham, Belper and Worthing, the 3 ft. 4 in. grid had been found very suitable for detailed planning.

164. Secondly, *flexibility*. The adoption of a square planning grid implies freedom to change direction, and the standard units had therefore to be designed to provide for all internal and external corner conditions. Similarly, in section, provision had to be made both internally and externally, for changes of level between ceiling heights (which might involve clerestory lighting) on opposite sides of any run of columns and changes of floor level in multiples of 10 in.

165. Thirdly, *the size and nature of the components*. The size of units was dependent upon such factors as height, length, bulk, and susceptibility to damage, which all, in various ways, affected production techniques, handling and storing at factory, transport to site and unloading and erection. Decisions had to be made early in the design stage concerning the degree to which units would be manhandled or mechanically handled. Initially, size was influenced by the basic module and its multiples. In terms of

*Ministry of Education Building Bulletin No. 7—Fire and the Design of Schools. (H.M.S.O. 4s. 6d.)

handling, weight was generally the deciding factor and most of the structural units—beam-webs, bottom boom units, cills, eaves, column heads and floor plates—were of such a size that they could be easily handled at the factory, and in loading and unloading, by one man.

166. All units in the system were of reasonable bulk and either small (cill, eaves and beam units) or narrow (beams) or slender (columns). Consequently for road transport they packed well and gave full payloads. Virtually no damage ever occurred.

167. With most systems of prefabrication the smaller the number of basic standard components, and the more of each type that is needed, the greater will be the saving—not only in production costs but in office and site work generally. The following table gives the number of components of each type in the system.

Table 5. Number of components

Unit	Number
Cill units	11
Columns	1 (plus 1 for some four storey internal conditions)
Boundary beams	3
Beam units	4
Decking slabs	2
Eaves units	14
Column heads	7

168. The actual number of columns is, of course, far greater since each type is obtainable in 10 in. increments. This was a requirement for vertical flexibility and, since moulds are easily "stopped off" in production, required detailed attention only in scheduling and erection.

169. Finally, *tolerances*. Excessively fine tolerance in manufacture may be of value in the factory assembly of components, but is not necessarily an advantage on the site, and may even mean unnecessary expenditure of time and money. The overall accuracy required in the erection of a frame of this sort was achieved by allowing sufficiently large in situ joints between components, rather than by calling for small casting tolerances. This applied particularly to beam units; with larger components, overlapping slip joints were designed to accommodate the relatively large tolerances expected, e.g., panel to column joint.

The components

170. Pre-cast lightly reinforced *cill units* (diagram 19) are bedded on to the site slab round the perimeter of the building. They have three main functions:

(1) to act as a drip and water bar;

(2) to "jig" the rest of the structure (since they are small units they can be accurately placed and levelled with ease);

(3) to provide a firm base for columns at datum level (F.F.L.) so that columns need not be carried down into the site slab; thus both single and multi-storey columns are identical for any given room height.

171. *Columns*—it was a requirement of the brief that column sections and cladding dimensions should be standard. A fresh study of the dimensional relationships of columns, external screens and internal screens was therefore made, and from this it appeared that the following conditions had to be met:

(1) a standard column section;

(2) standard external screens with no "make-up" or corner pieces;

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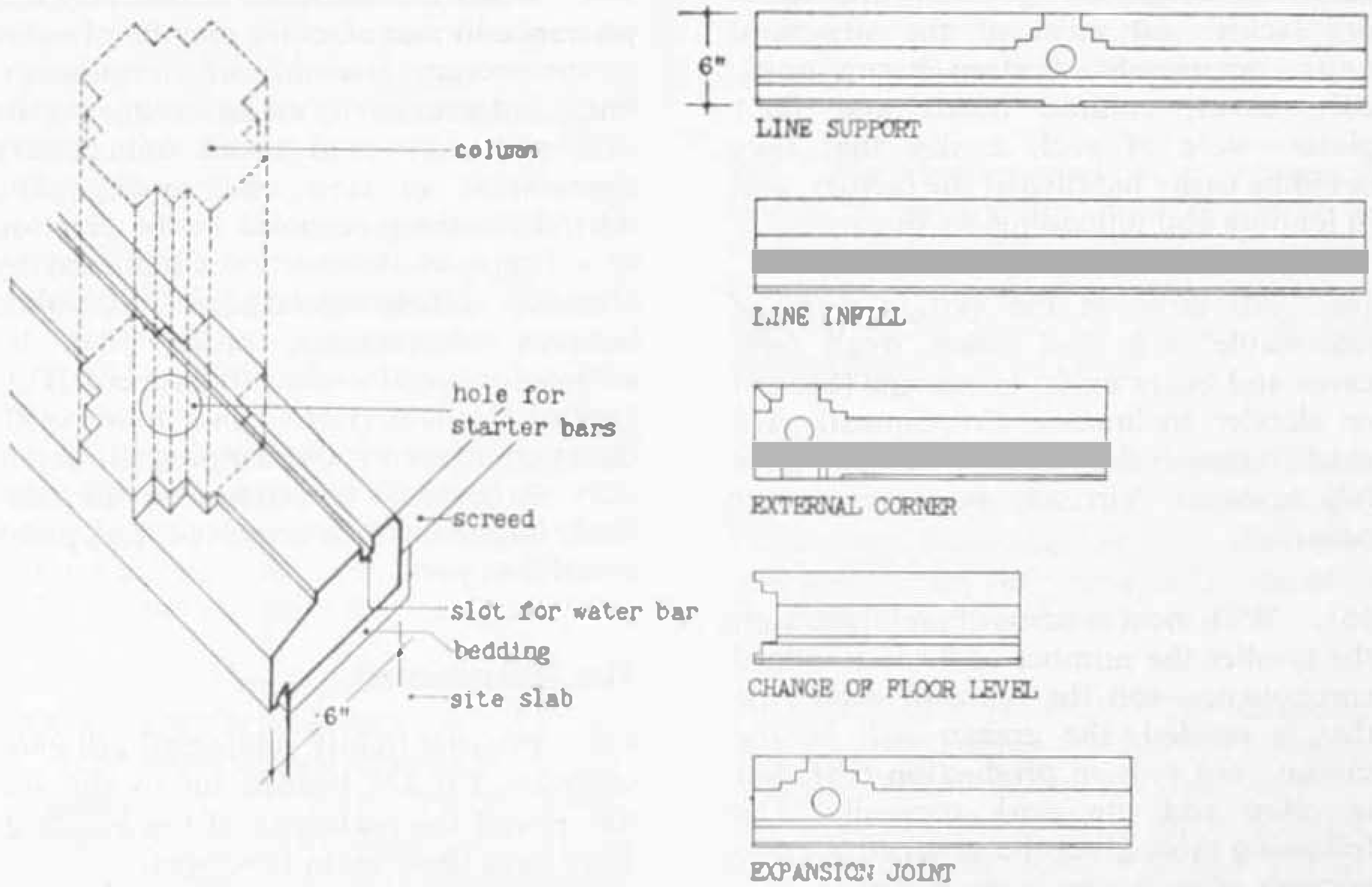

Diagram 19. CILL UNITS

(3) standard internal screens with no cutting;

(4) the internal face of the external screen, and the faces of internal screens, to be equidistant from the grid line;

(5) the internal and external screen grid to coincide with the structural grid.

172. The last of these conditions, which is one of the classic problems in the design of prefabricated systems, was accepted because the alternative, of placing the cladding half a module outside the columns, would cause interruption in the internal spaces and interference with equipment. The resolution of these requirements, and the logic of the column profile, are shown in diagram 20.

173. Columns are pre-cast and pre-tensioned on a long line system with four 0·200 in. diameter high tensile steel wires, each wire developing a stress of 5,200 lbs. They are almost entirely of cruciform profile, and 6 in. by 6 in. overall—the one variation, introduced for multi-storey internal use, is a 6 in. square column which may be used in any internal position, but which is needed especially for certain heavy loadings where the building rises to four storeys.

174. Each column has a tube cast into the foot to take the starter bars which protrude from the cill unit. This tube is grouted up (after plumbing) through pre-formed grout holes. Since cladding,

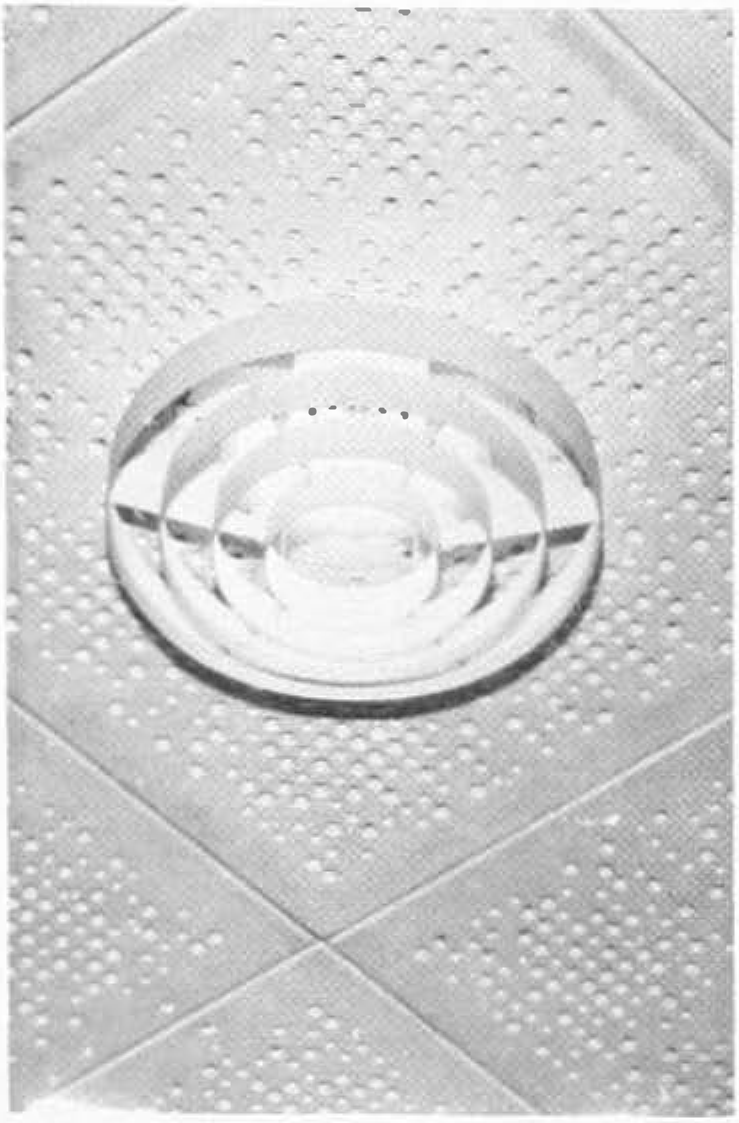

Plate 1. GYMNASIUM LIGHT

Plate 2. STRIP LIGHT

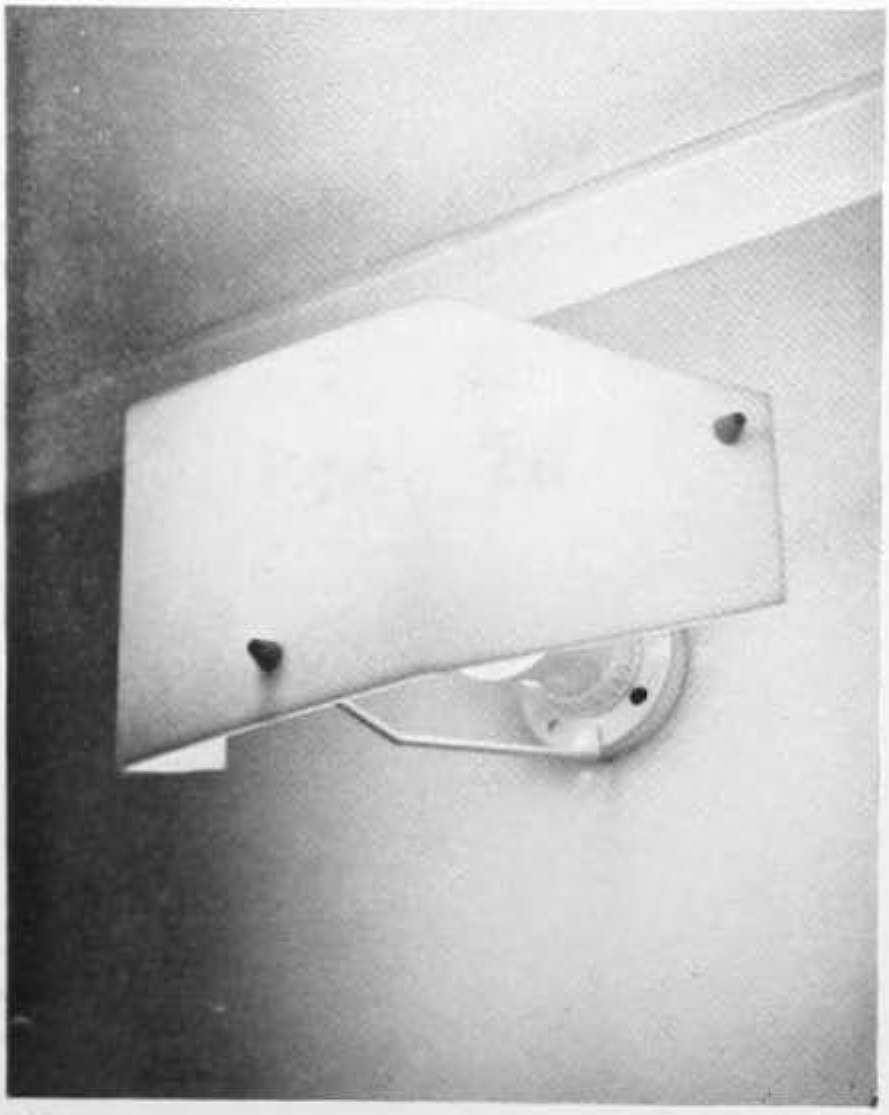

Plate 3. WALL LIGHT

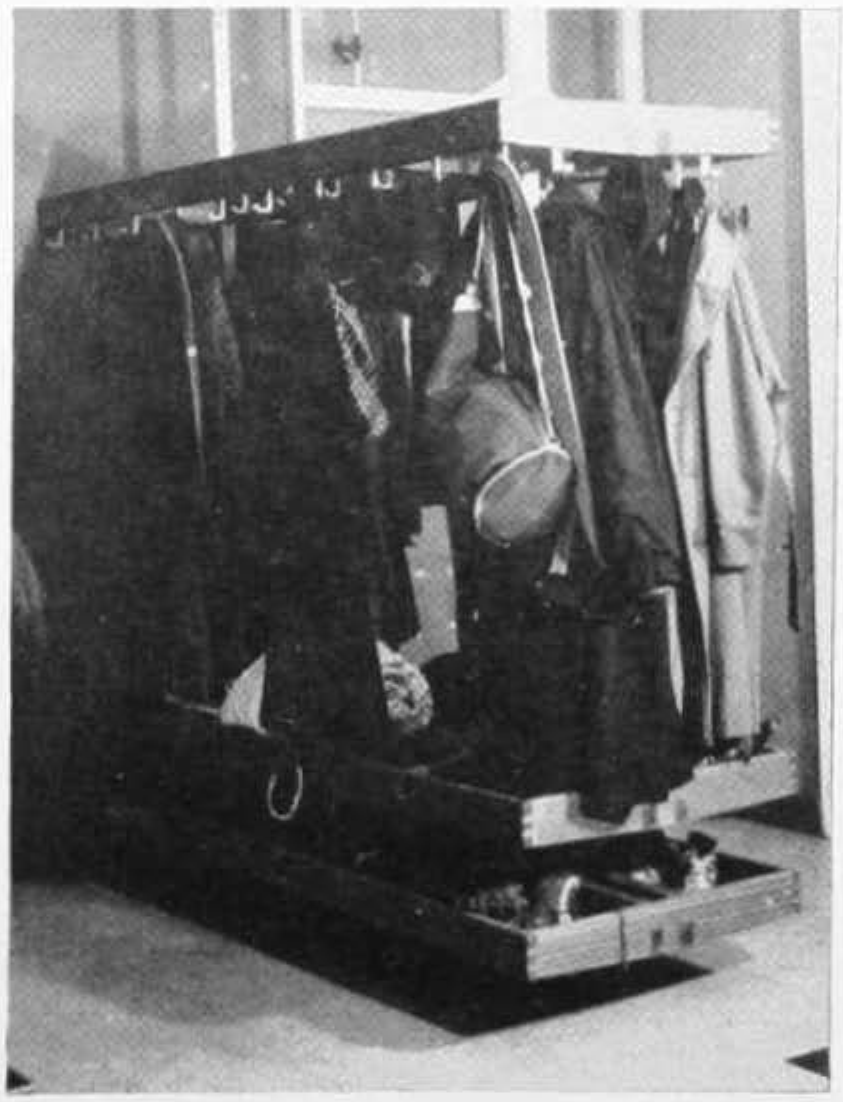

Plate 4. COAT AND SHOE RACKS

Plate 5. VITREOUS SPRAY BASIN

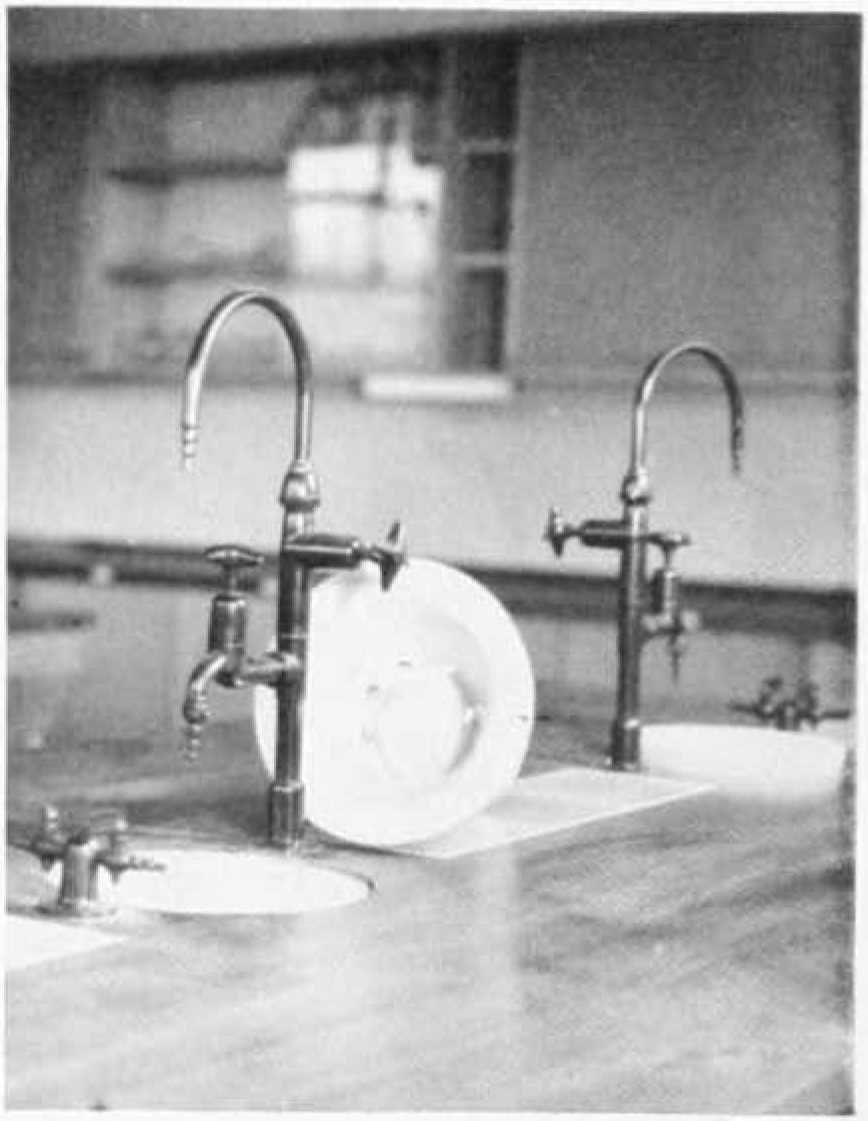

Plate 6. ACID DILUTION POT

Plate 7. FIRECLAY SPRAY BASINS WITH ELECTRIC WATER HEATER

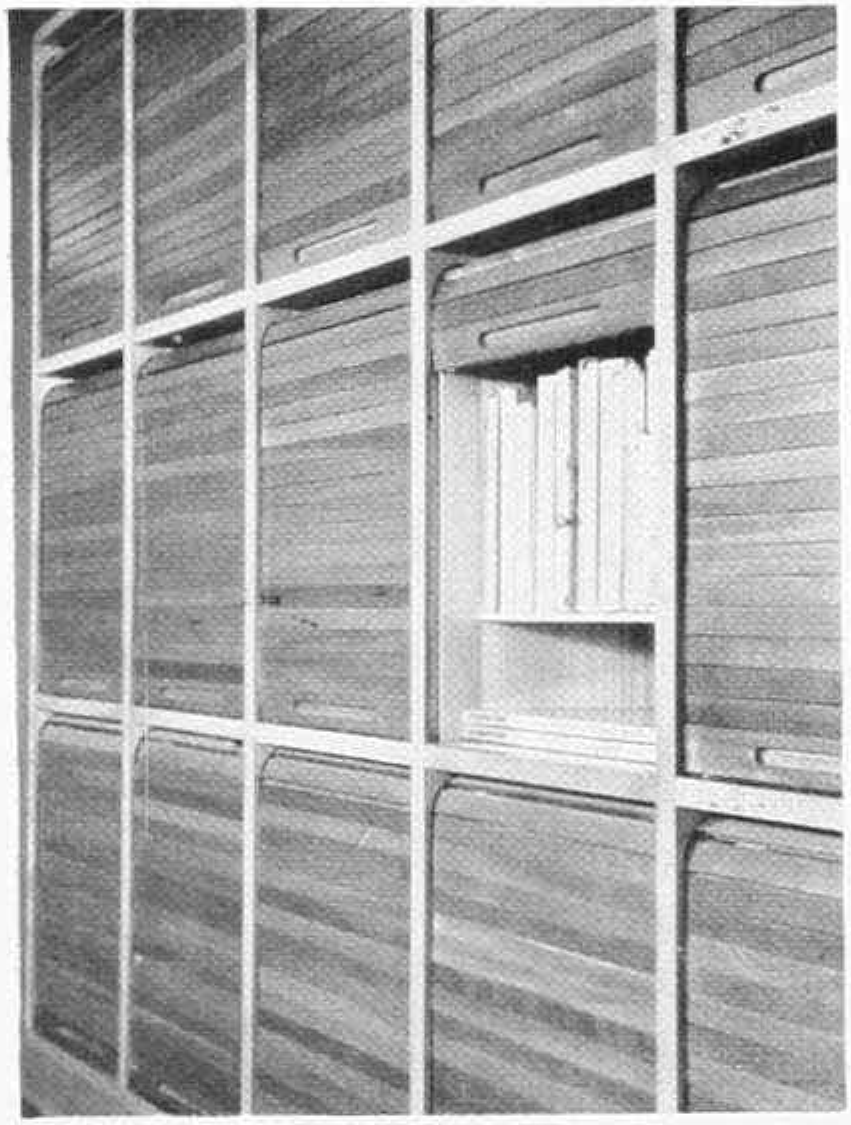

Plate 8. BOOK LOCKERS

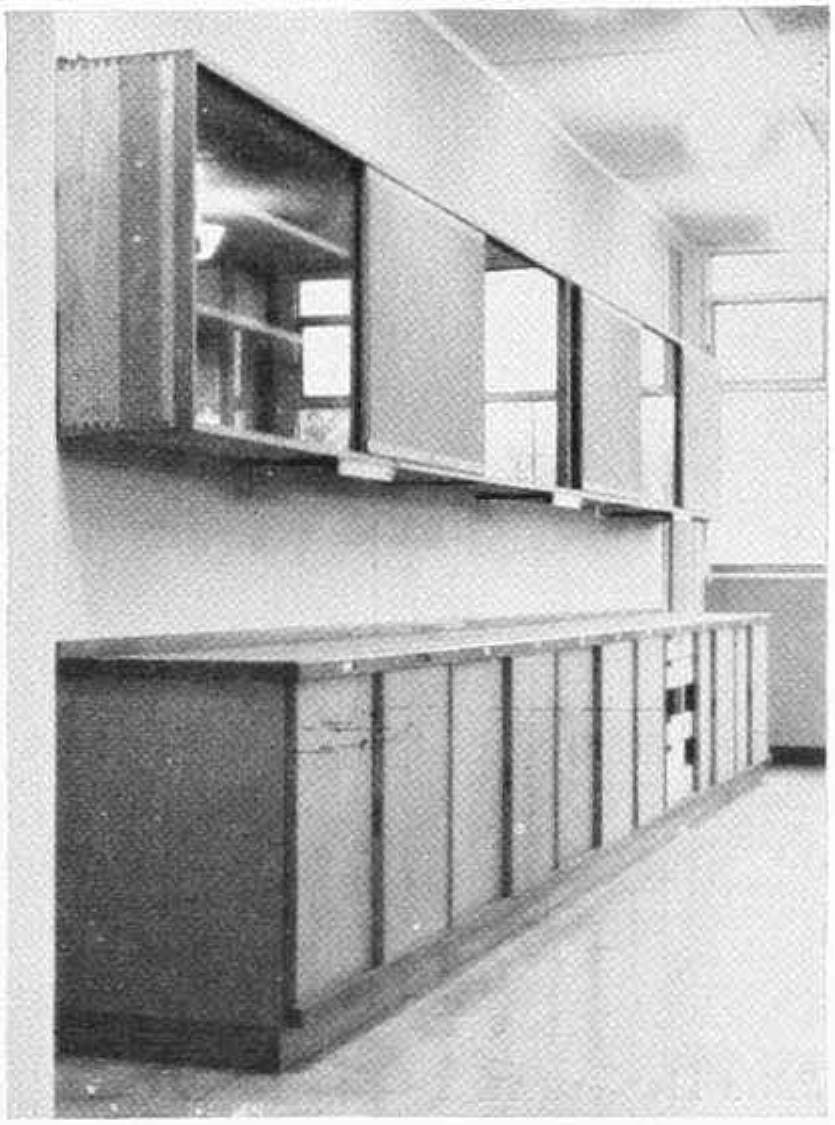

Plate 9. WALL BENCH AND CUPBOARDS

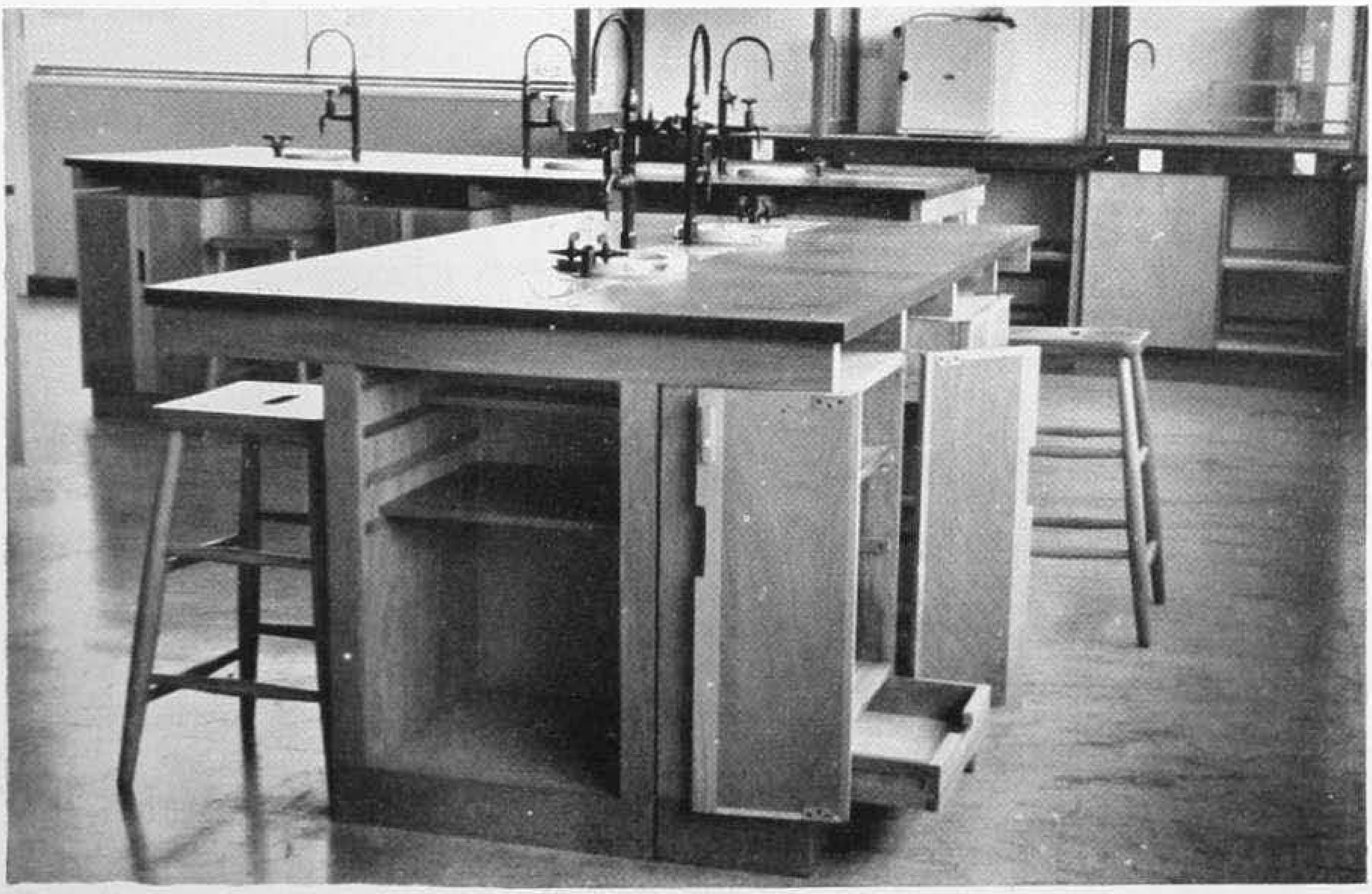

Plate 10. ISLAND BENCHING

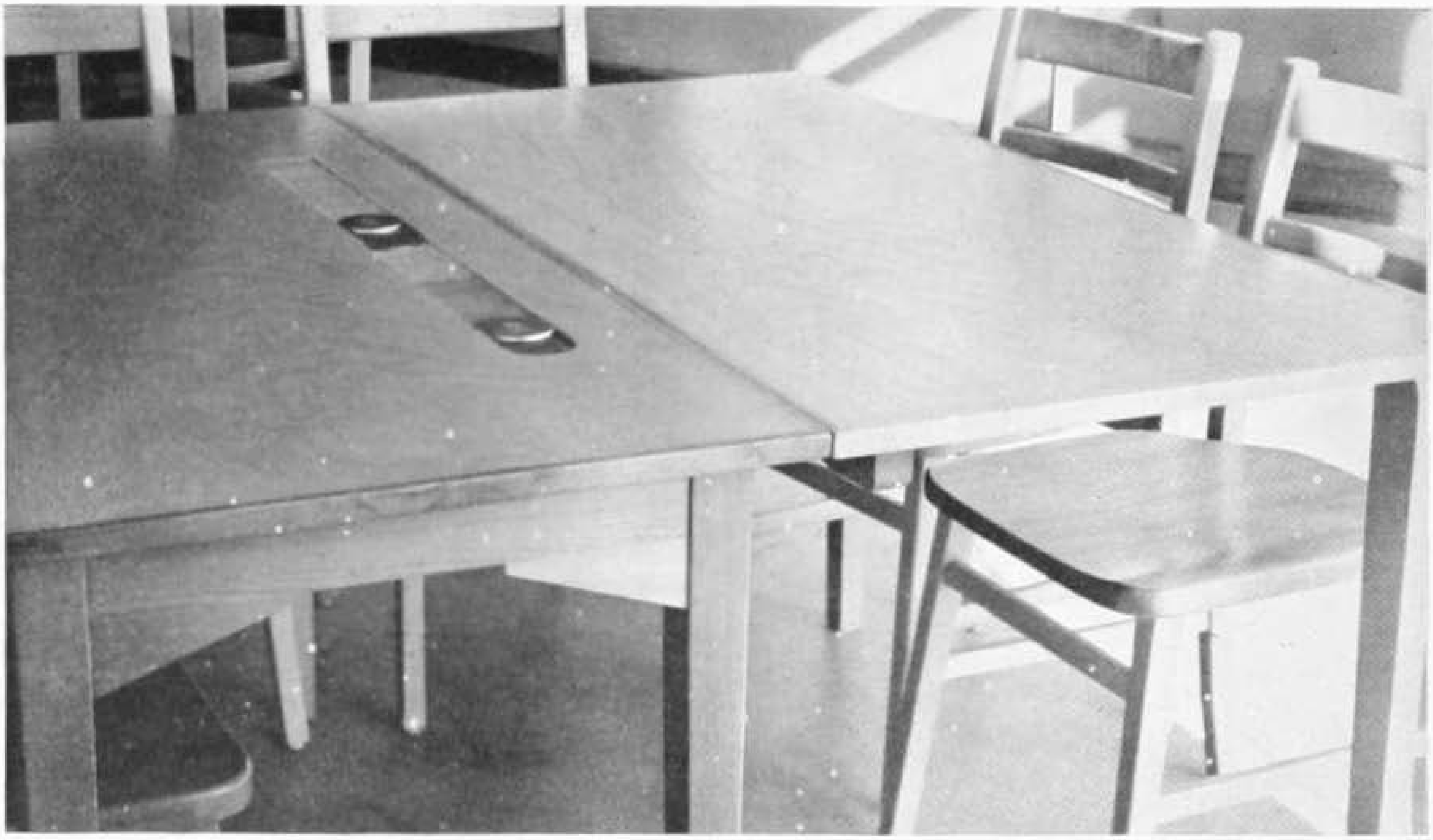

Plate 11. DUAL TEACHING TABLE WITH CLIP-ON DINING EXTENSION

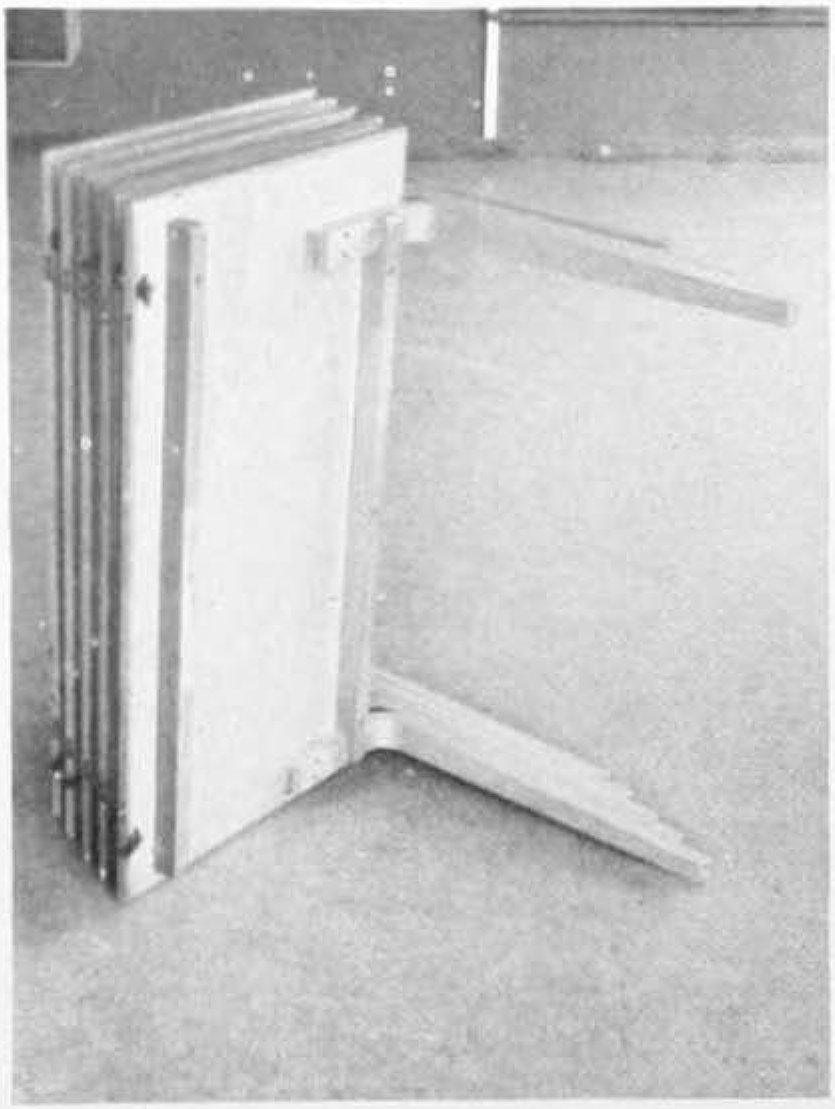

Plate 12. NESTING EXTENSION TABLES

Plate 13. DUAL LOCKER DESK

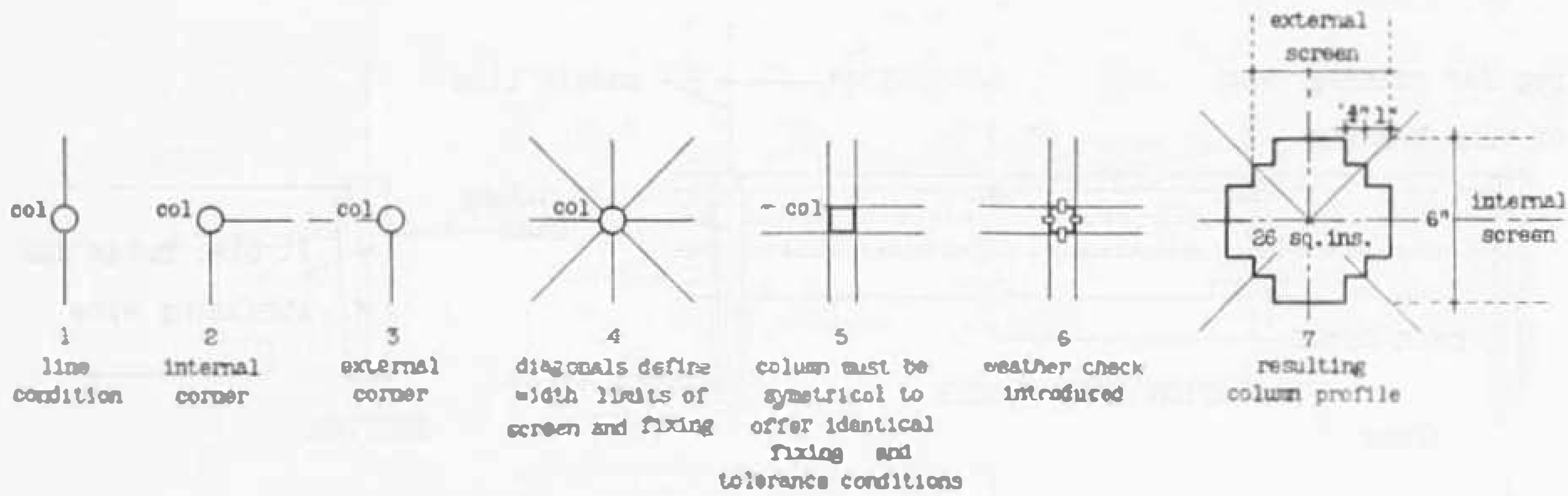

Diagram 20. DEVELOPMENT OF COLUMN PROFILE

windows and doors are all attached with friction fixings it was not necessary to cast holes into the column; it is therefore entirely standard and may be placed any way round. The columns are positioned at 3 ft. 4 in., 6 ft. 8 in. or 10 ft. centres round the structural bay. Each is designed to take a maximum load of 25 tons, and is prestressed in order to counter the bending moment which develops under eccentric loading and wind loading.

175. *Column heads* (diagram 23) are made of ordinary reinforced concrete and are of several types. All (with the exception of the external corner type) provide one or more beam seatings.

176. *Boundary beams* (diagram 22) are of ordinary reinforced concrete and span between column heads, while being supported directly on the columns. In

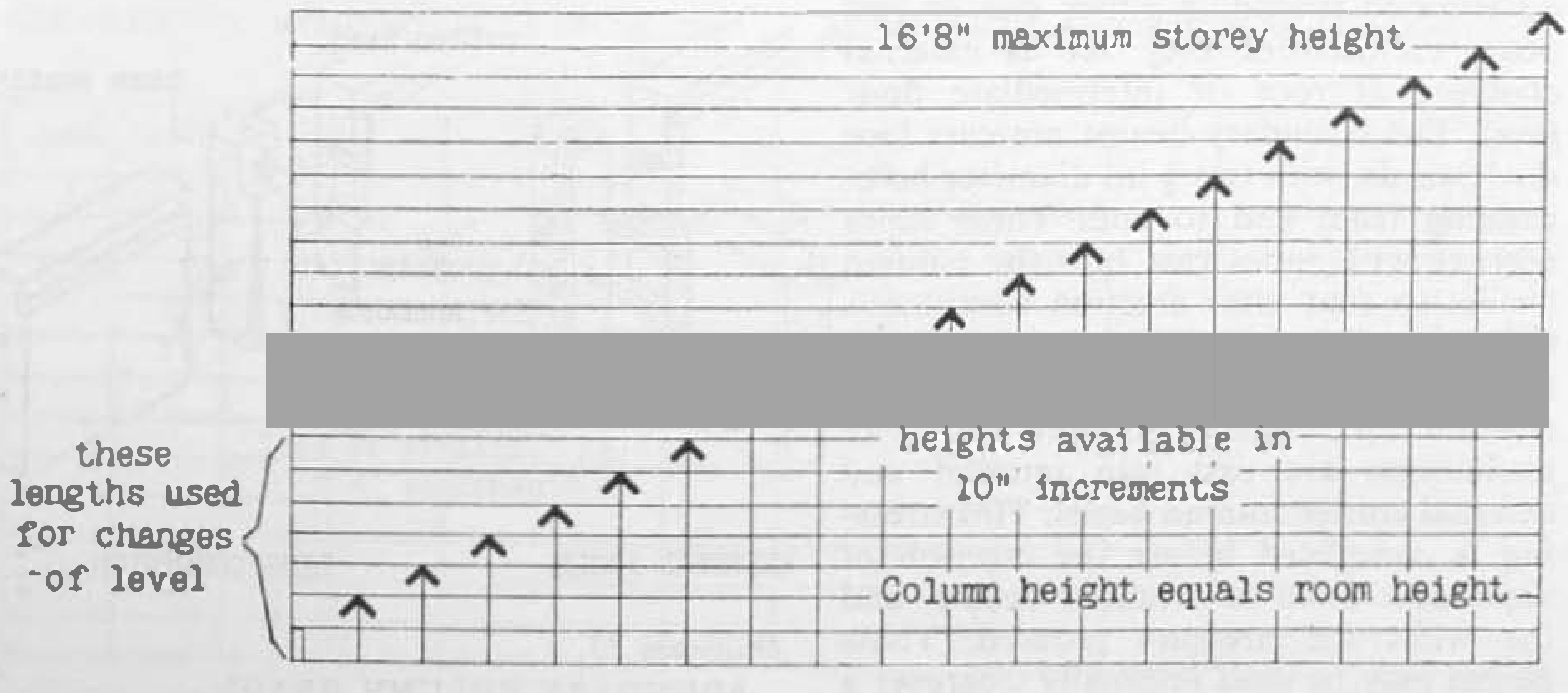

Diagram 21. COLUMN LENGTHS

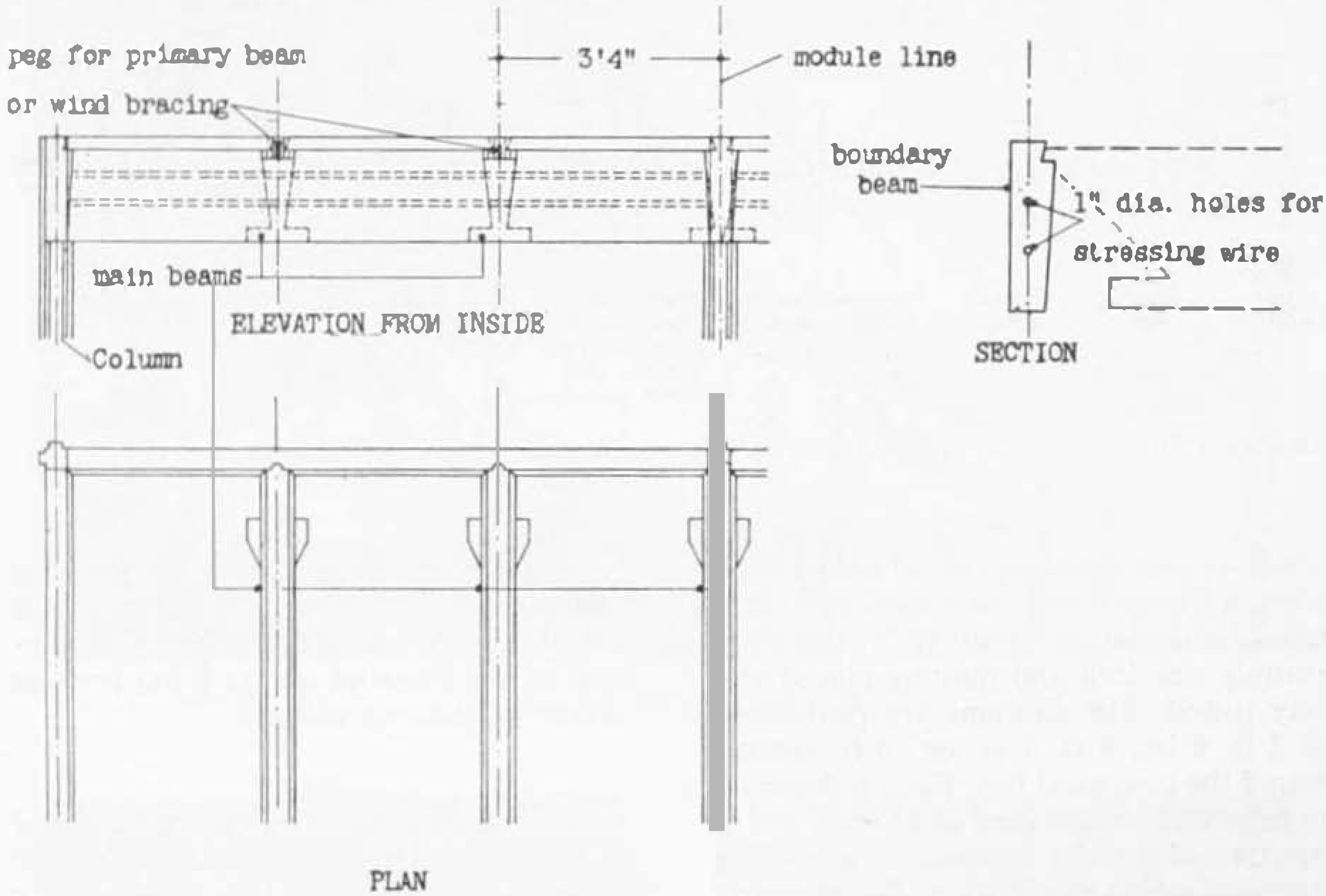

Diagram 22. BOUNDARY BEAM

addition to providing either one or two beam connections they act as external cladding at roof or intermediate floor level. The boundary beams are cast face downwards, with two ½ in. diameter holes running from end to end. These holes register with tubes cast into the column heads, so that after erection continuous 0·276 in. diameter H.T.S. wires can be threaded through a complete bay side and stressed up. Pockets for the one wire anchorages are cast into internal and external corner column heads. This stressing is completed before the erection of dependent main or trimmer beams, and the wires are pressure grouted. These beams may be used internally wherever a flush face is required, e.g., at changes of level or in staircase wells.

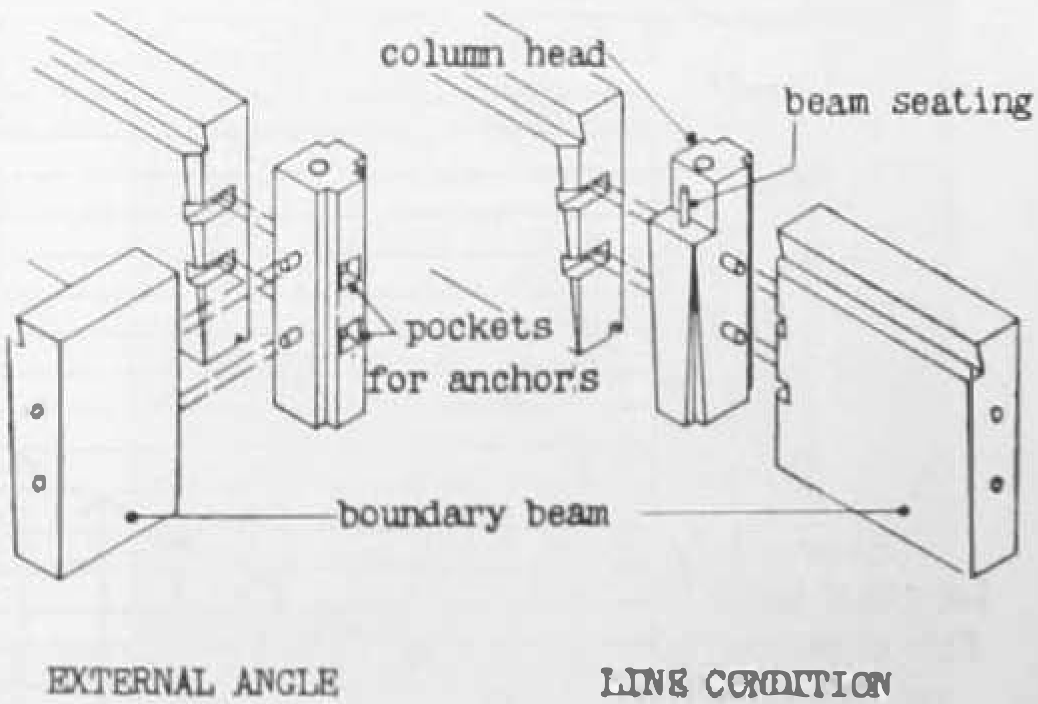

Diagram 23.
BOUNDARY COLUMN HEADS

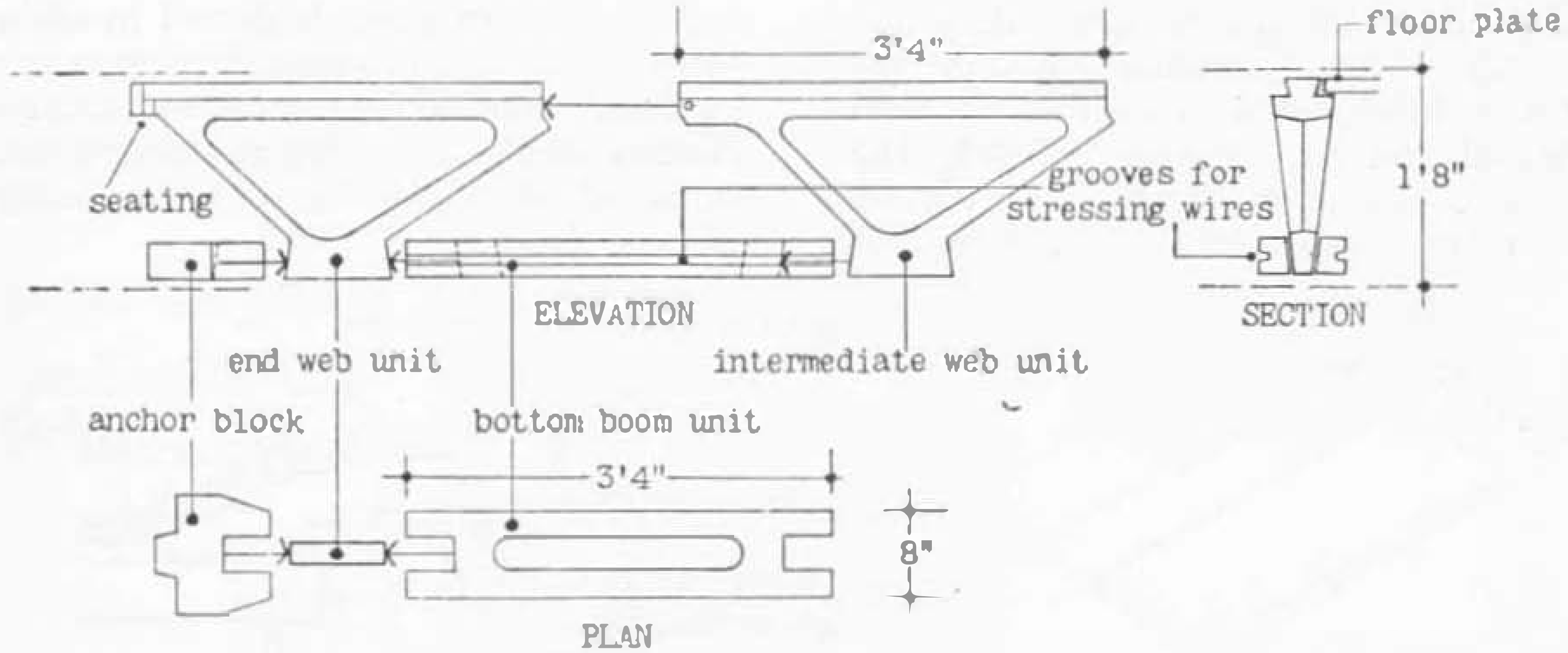

Diagram 24. MAIN BEAM COMPONENTS

177. *Trimmer beams* are used internally where support is needed for main beams. They have the same end fixing requirements as main beams, and provide either two or four beam seatings and are not "doubled up" at structural bay limits.

178. *Main beams* (diagrams 24 and 25); with columns, column heads, boundary beams and trimmer beams in position round any structural bay, a skeleton is established with main beam connections automatically available at 3 ft. 4 in. centres round the whole perimeter. Main beams are built up to form the required span (6 ft. 8 in. to 46 ft. 8 in.) from a small range of components consisting of end units, web units and bottom boom units. Each beam therefore comprises two end units, two anchor blocks and the requisite number of bottom boom and web units assembled and mortar jointed on site. Web units and bottom boom units are so shaped as to be interlocking. One, two or three (the exact number depending on the span) 0·276 in. diameter H.T.S. wires are

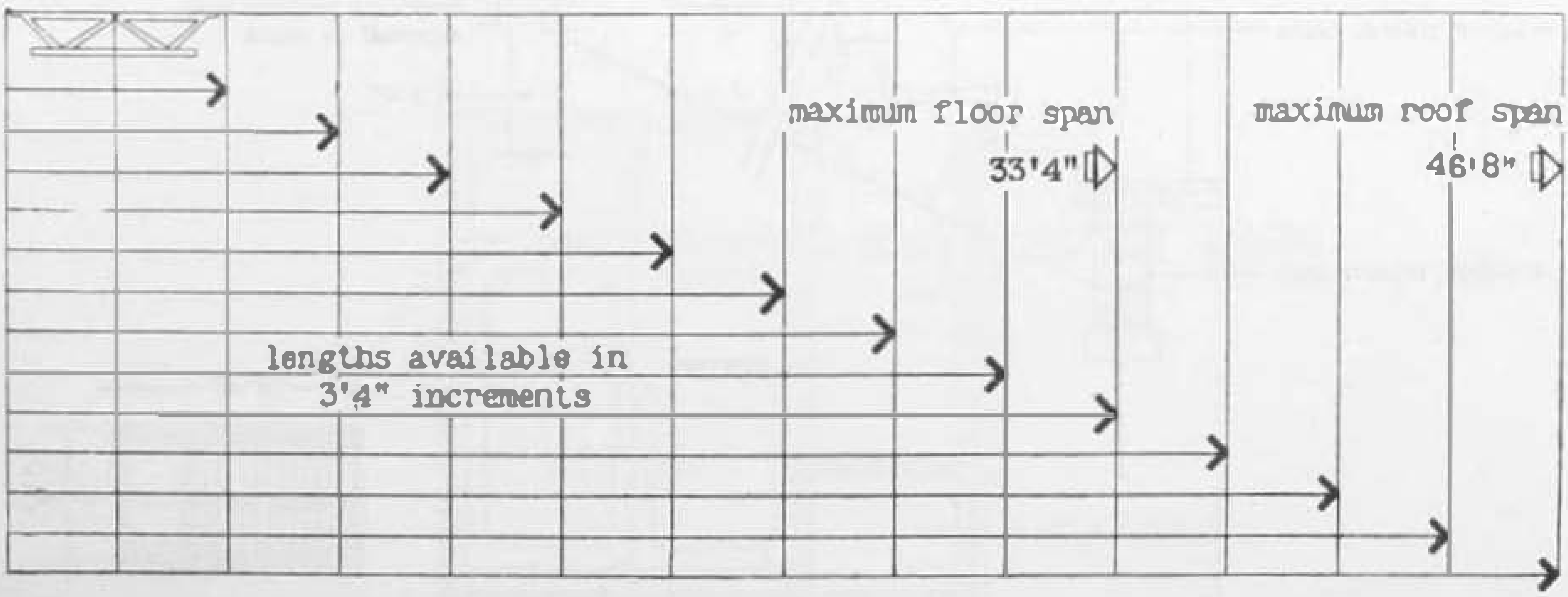

Diagram 25. MAIN BEAM LENGTHS

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passed down grooves on each side of the bottom boom, threaded through the anchor blocks and the beam is then stressed and the grooves pointed. The lattice character of the assembled beam allows very generous paths for services and the bottom boom is slotted to allow small service drops to pass through at any modular intersection, also to accommodate plates for ceiling suspension and softwood, dovetailed blocks for a variety of other fixings.

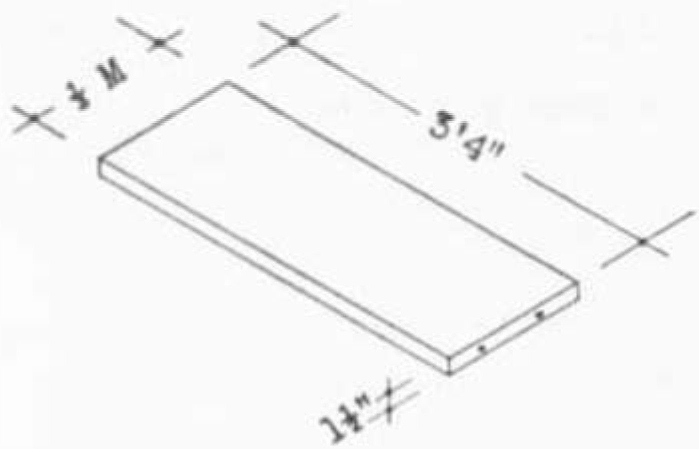


Diagram 26. FLOOR PLATE

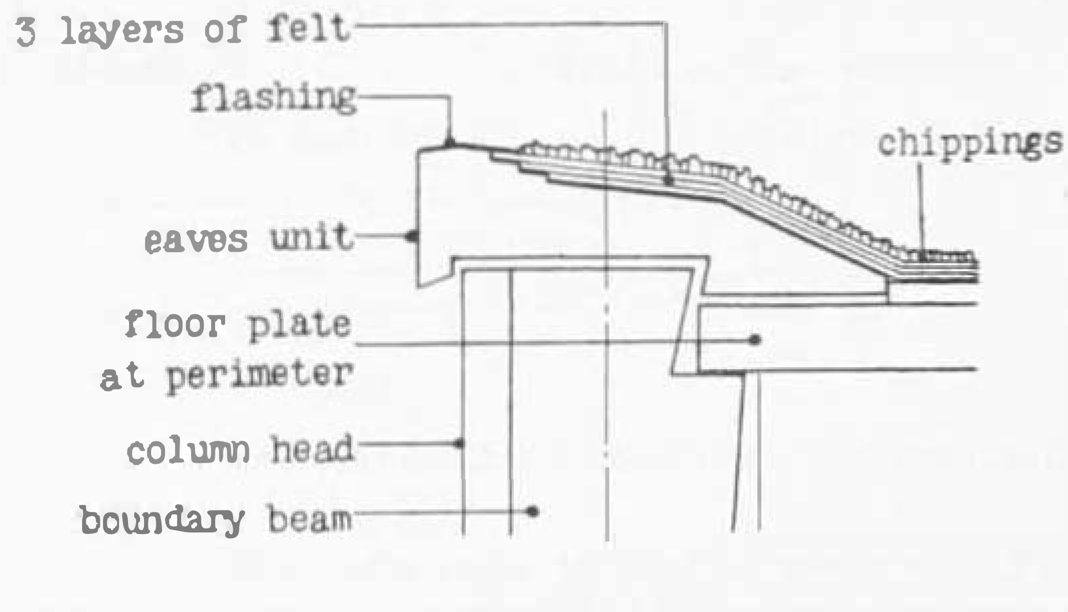


Diagram 27. EAVES UNIT

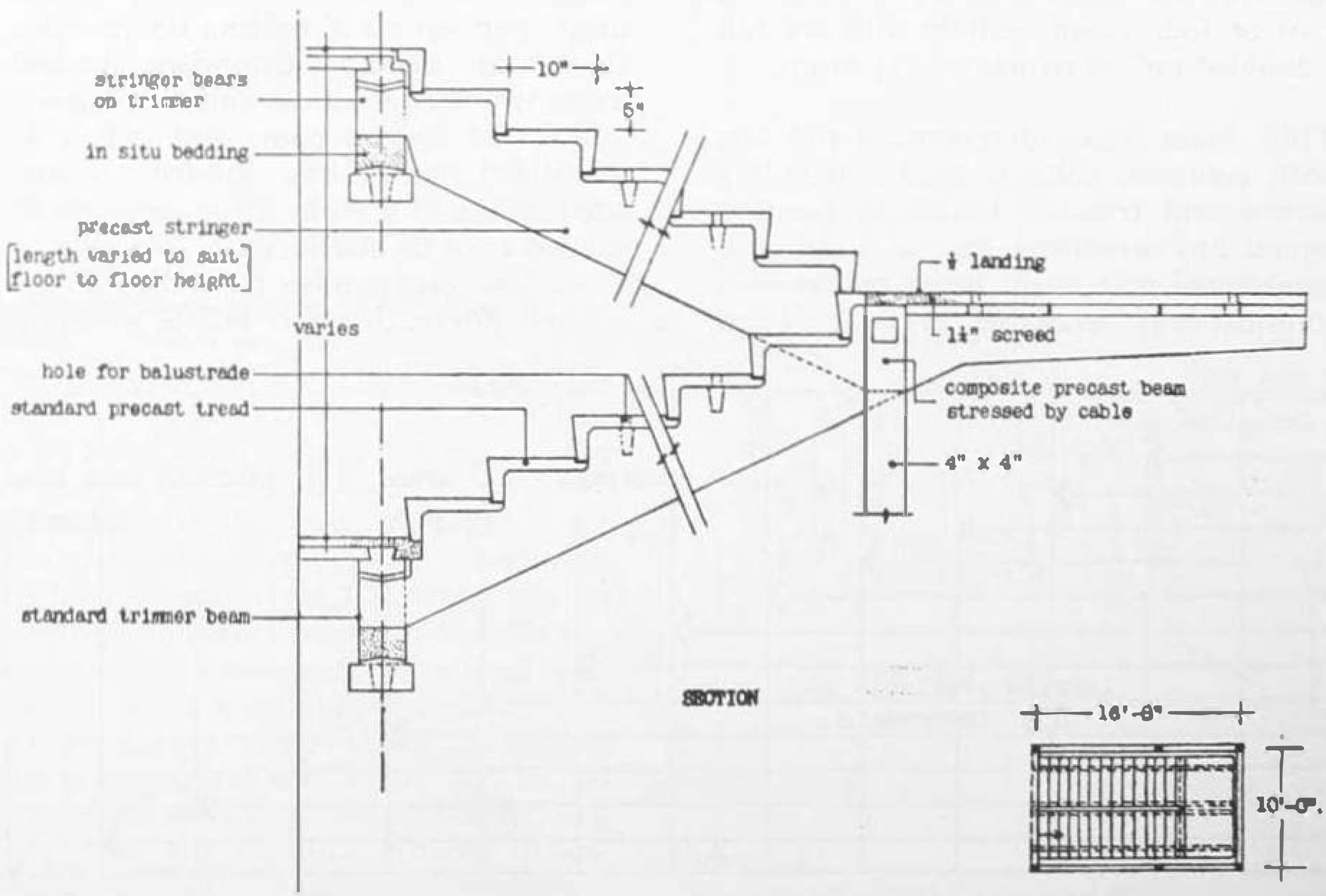


Diagram 28. STAIRCASE

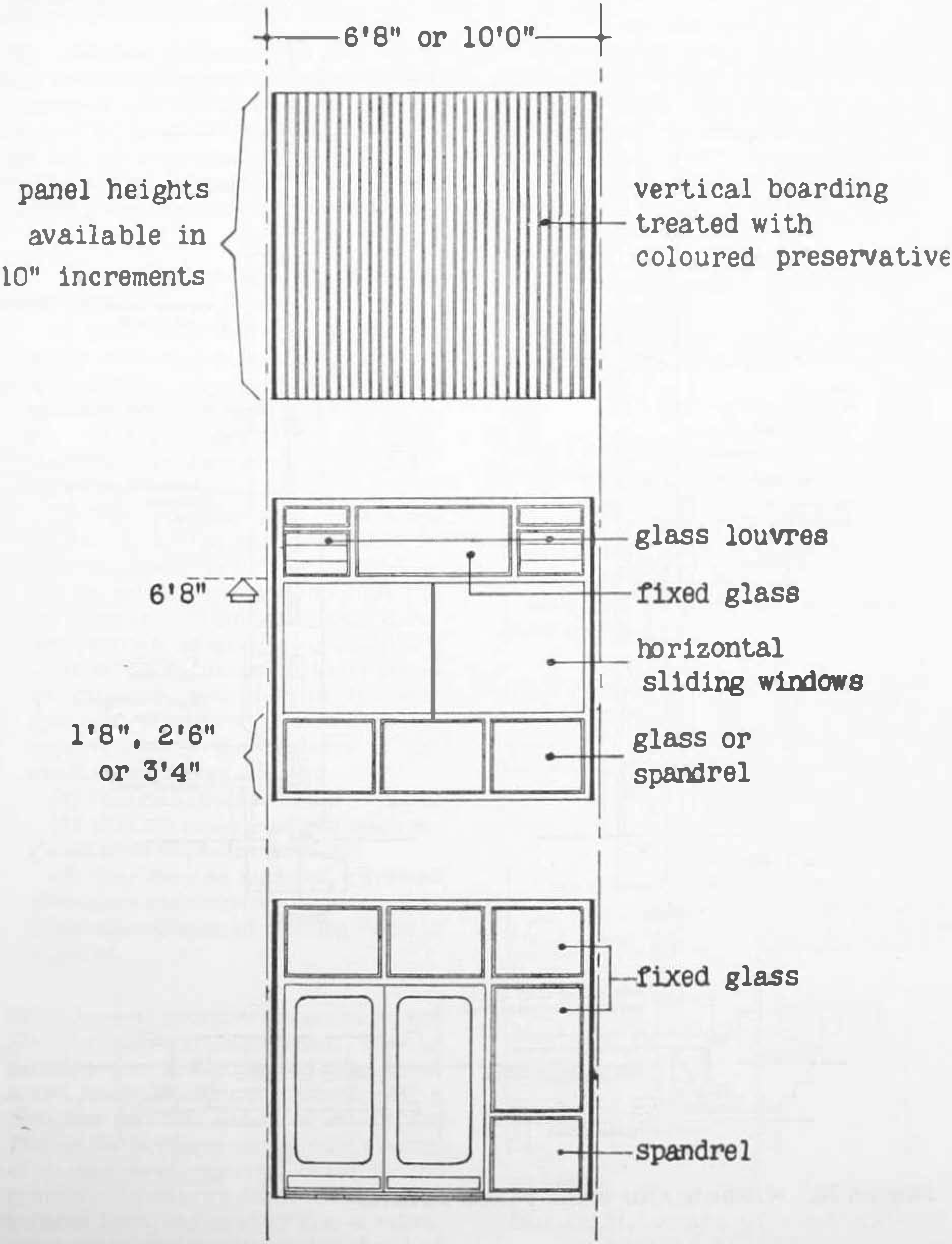


Diagram 29. TYPICAL CLADDING PANELS

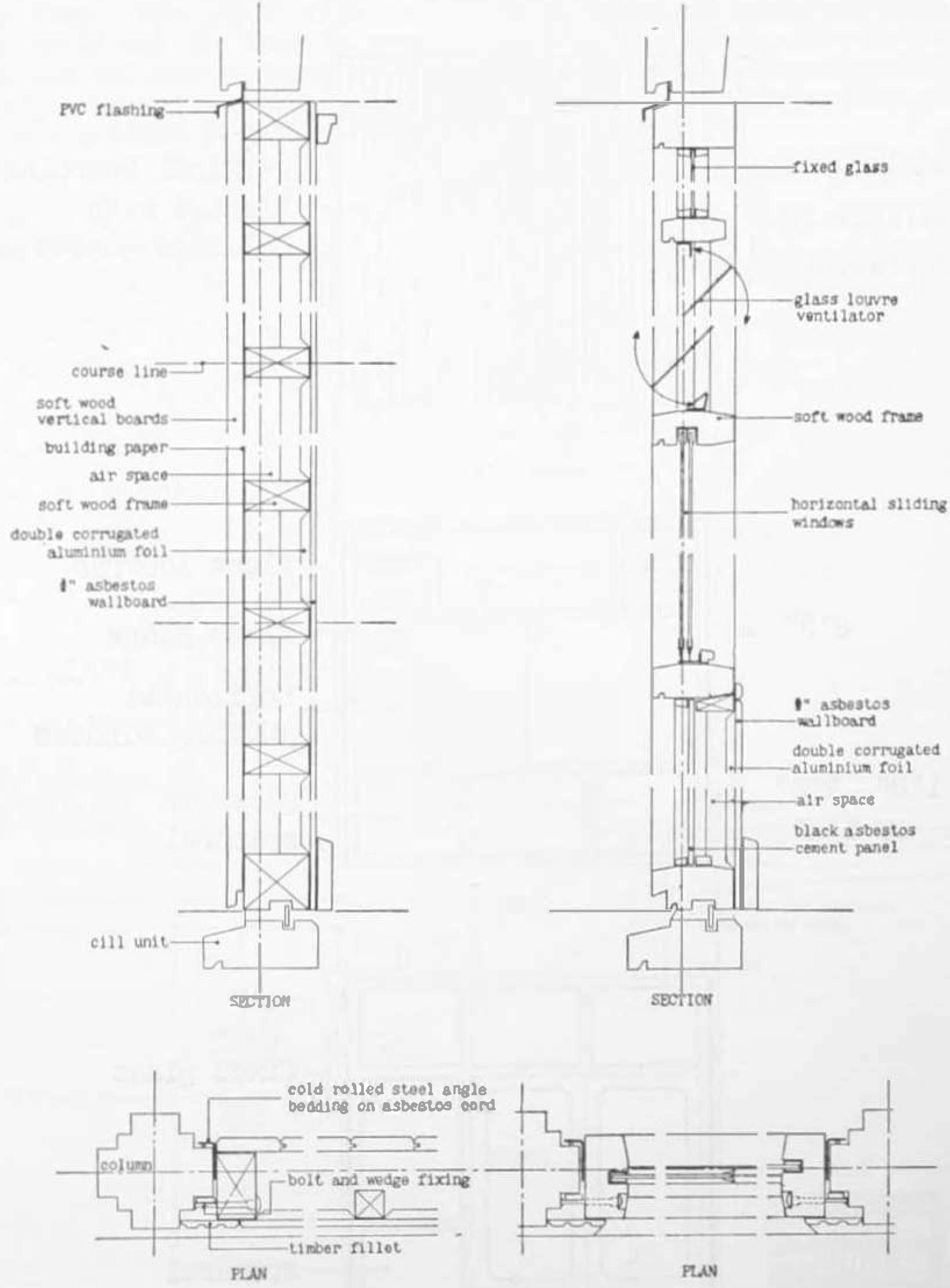


Diagram 30. WINDOW AND WALL PANEL DETAILS

179. *Windows* (diagrams 29 and 30)—after reviewing the methods of providing openings it was decided that the requirements of (a) good daylight (b) wide openings and (c) controlled ventilation could best be achieved by using a combination of sliding windows and top ventilation.

180. Sliding windows have the following advantages:

(1) when open they do not obstruct people moving about outside the building—children are particularly prone to accidents from projecting windows. It was therefore unnecessary to plan "hazards" by means of paving or planting;

(2) they provide good ventilation control. It is true that sometimes in gusty weather they do not function as well as side hung casements, but the top ventilators would, on these occasions, provide adequate compensation;

(3) no large intermediate mullions are required, even for 10 ft. wide openings, and there is a consequent improvement in the efficiency of the window as a source of light;

(4) they make wide openings possible;

(5) they are easily fixed and easily reglazed from inside the building;

(6) they may be made of unframed plate glass and therefore no painting or other maintenance of opening lights is required.

181. *Internal partitions* (diagrams 31 and 32)—the essential requirement for the partition was that it should offer good sound insulation between rooms, say, a reduction of the order of 40-45 db. During the development period a number of designs were explored, based on the principle of using two dense but thin skins isolated from one another (i.e. a refinement of the stud partition), but they had to be discarded as too expensive. Eventually it was decided to use a medium density concrete block plastered on both sides, since it was known that this traditional method had every chance of success. In order to minimise cutting and chasing, and to speed up laying, a series of special modular blocks was designed; it was found that all the dimensional requirements could be met by using three standard blocks. Bulkheads were provided above partitions in the ceiling space to prevent sound passing round the partition. (See diagram 33).

182. *The ceilings* (diagrams 34 and 35) are metal reinforced pre-cast fibrous plaster panels, suspended by mild steel plates from the bottom boom of the beams. There are two types—plain and "perforated", both of which have at least ½ hour fire resistance and are Class A flame spread.

183. *Blind boxes* (diagram 36) form an integral part of the ceiling system, designed so that blinds can be drawn into the ceiling and do not obstruct glazing at window head.

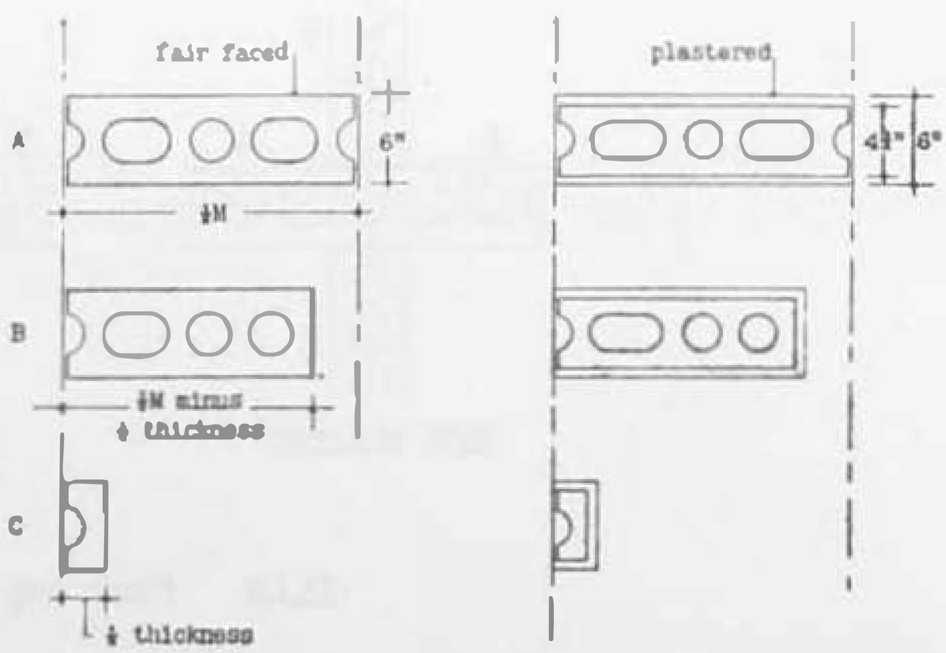


Diagram 31. PLANS OF STANDARD PARTITION BLOCKS

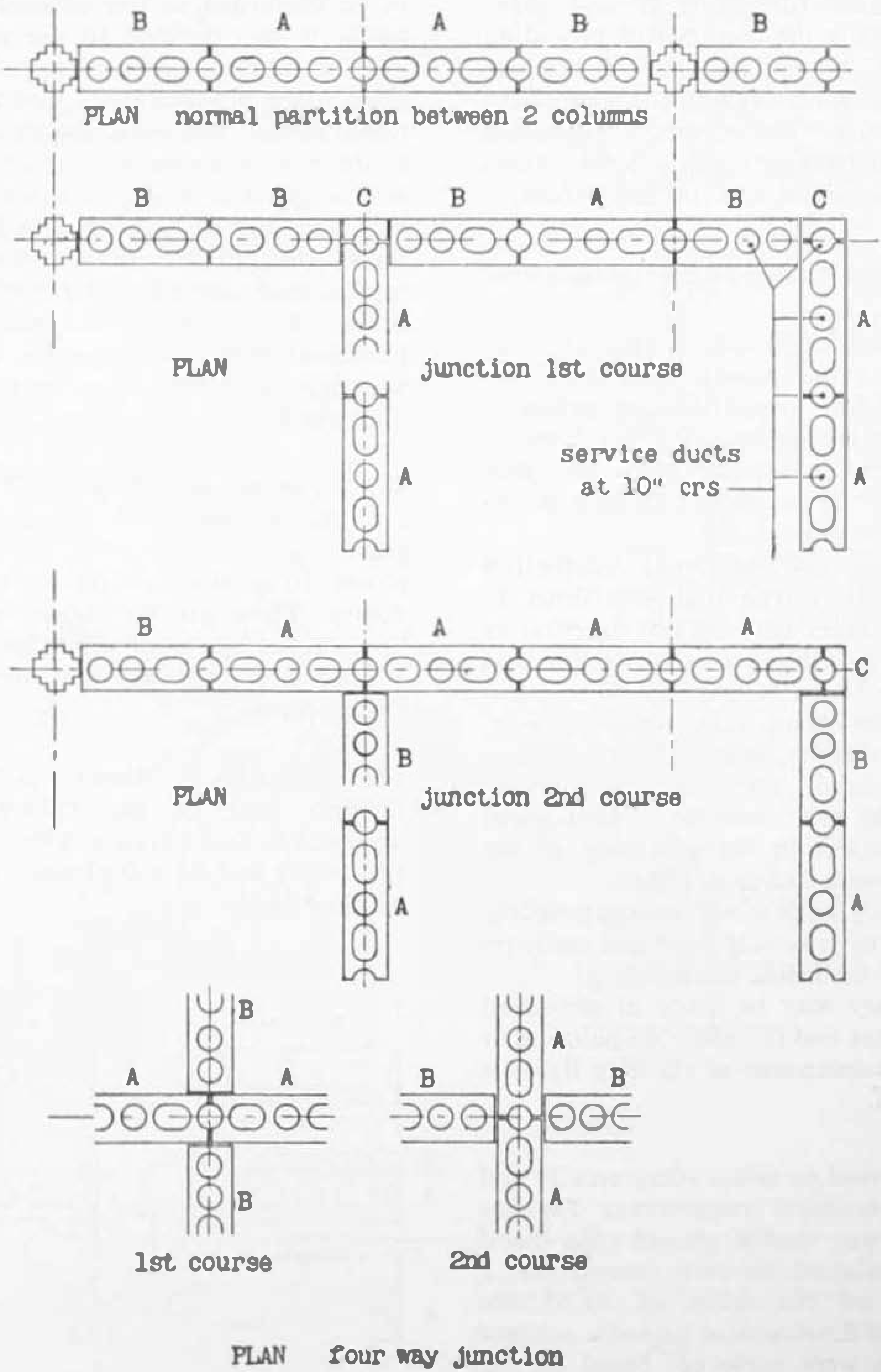


Diagram 32. PARTITION BLOCKS ASSEMBLY

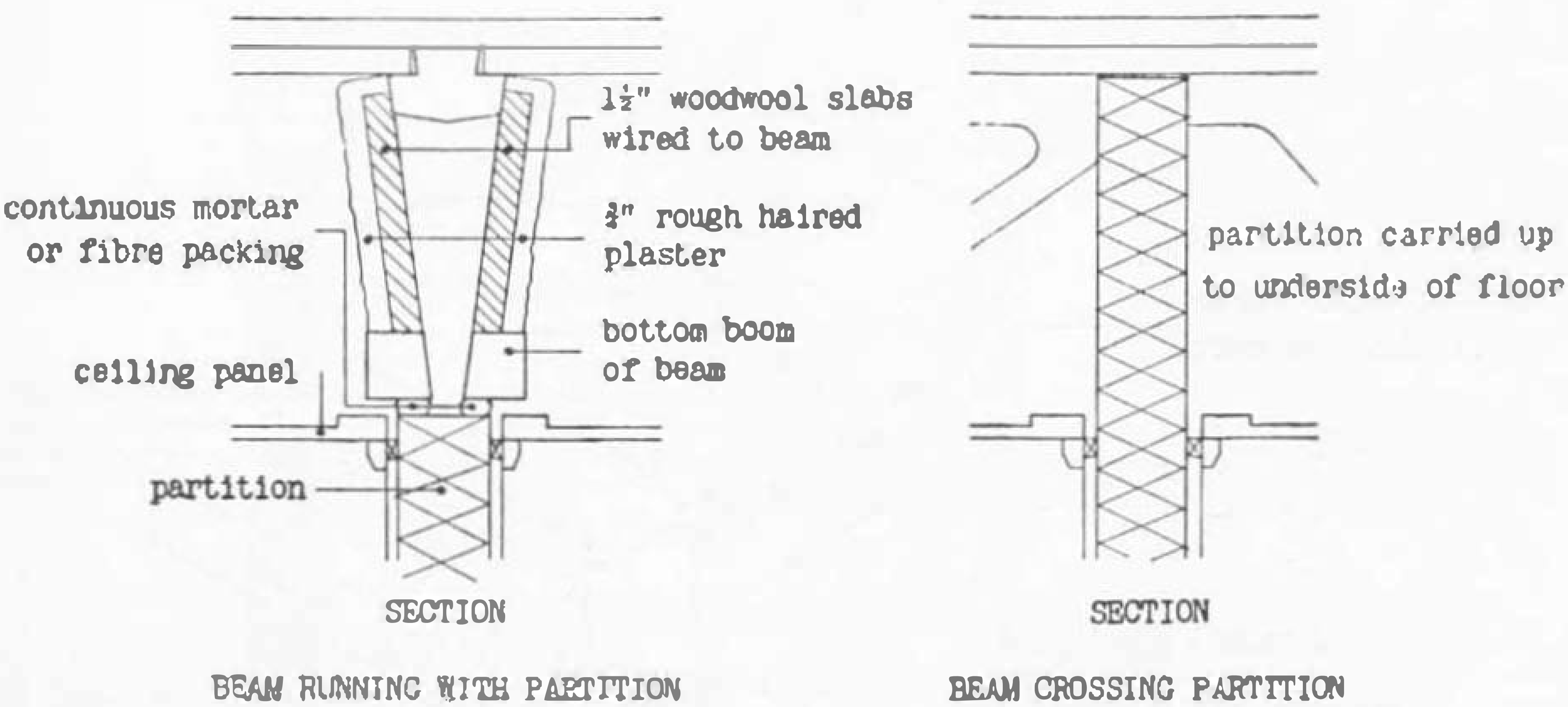
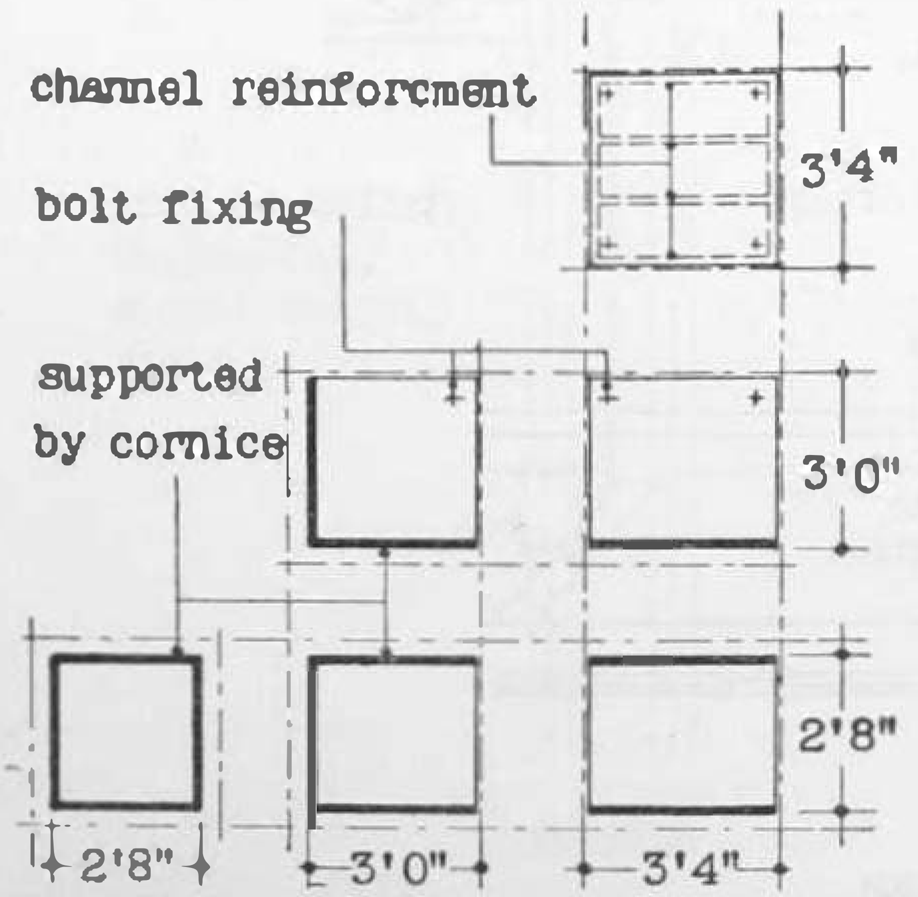


Diagram 33. SOUND REDUCING BULKHEADS



An identical range is available with random perforations (made in same moulds).

Diagram 34. PLANS OF STANDARD CEILING PANELS

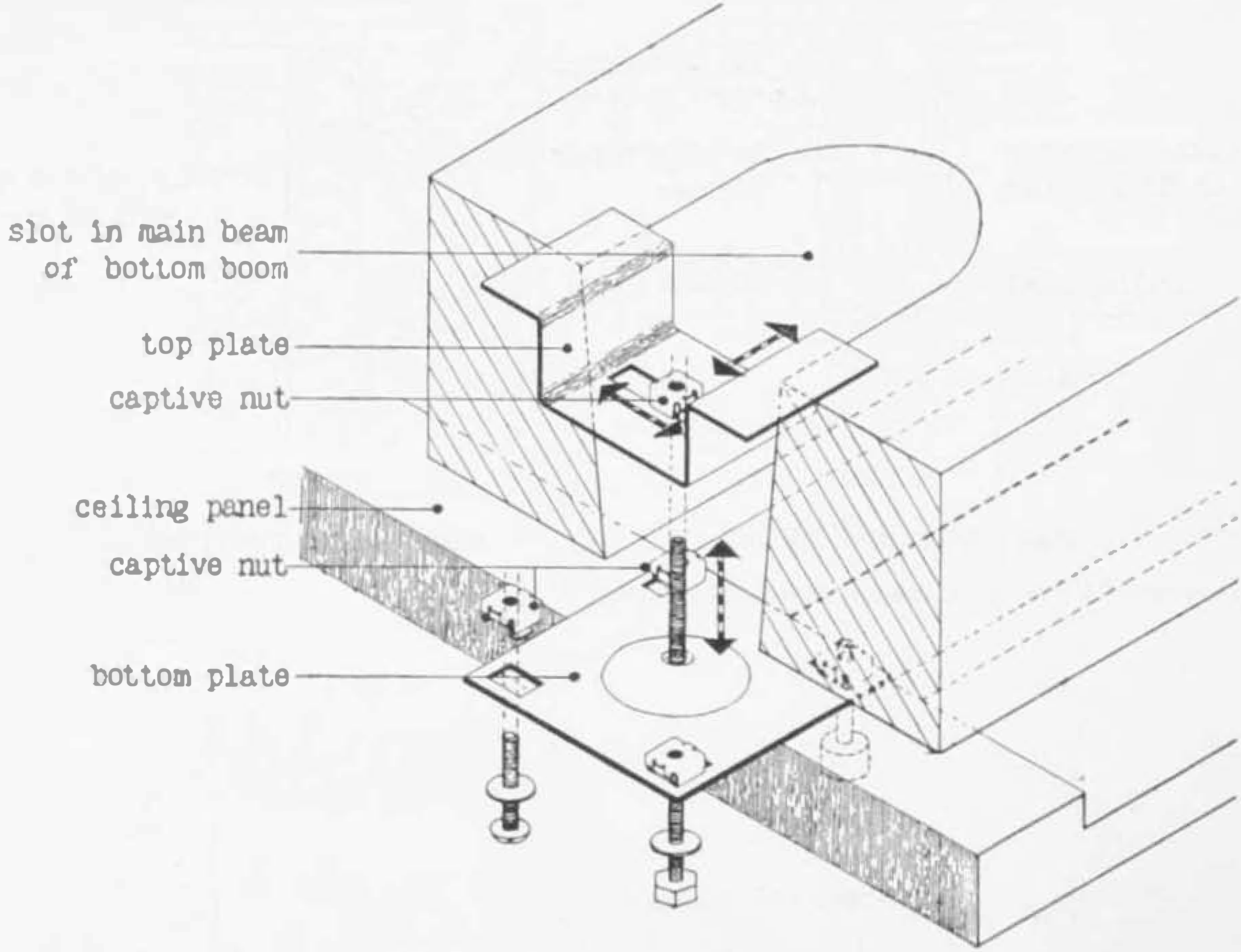


Diagram 35. CEILING PANEL SUSPENSION

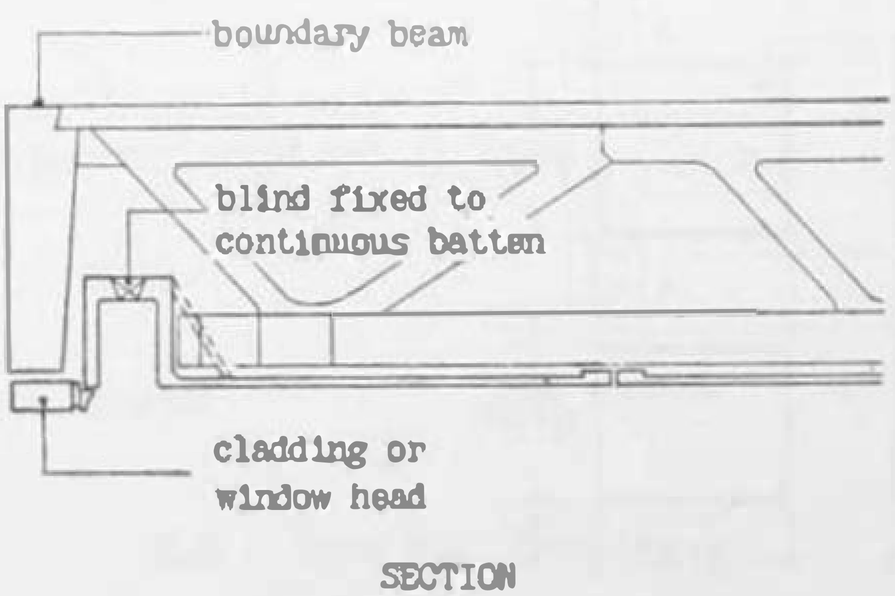
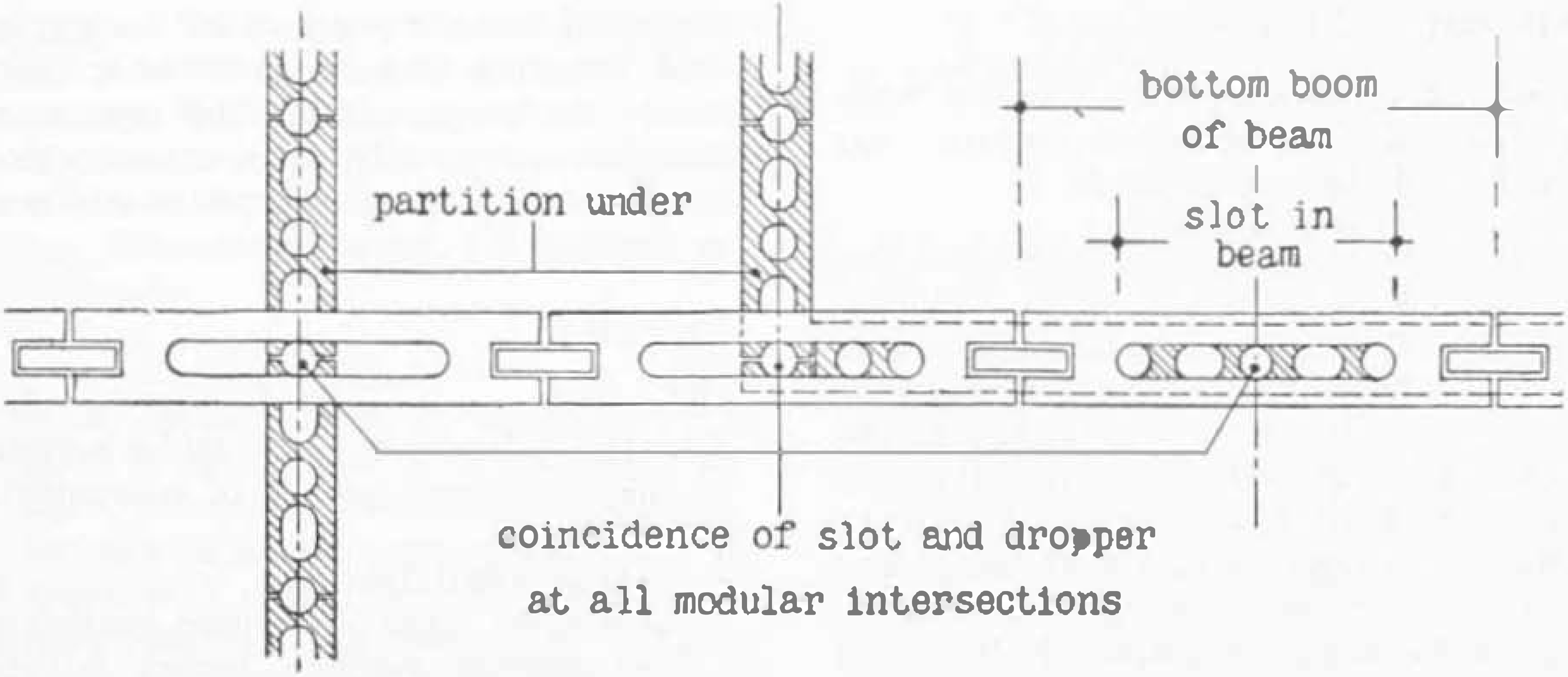
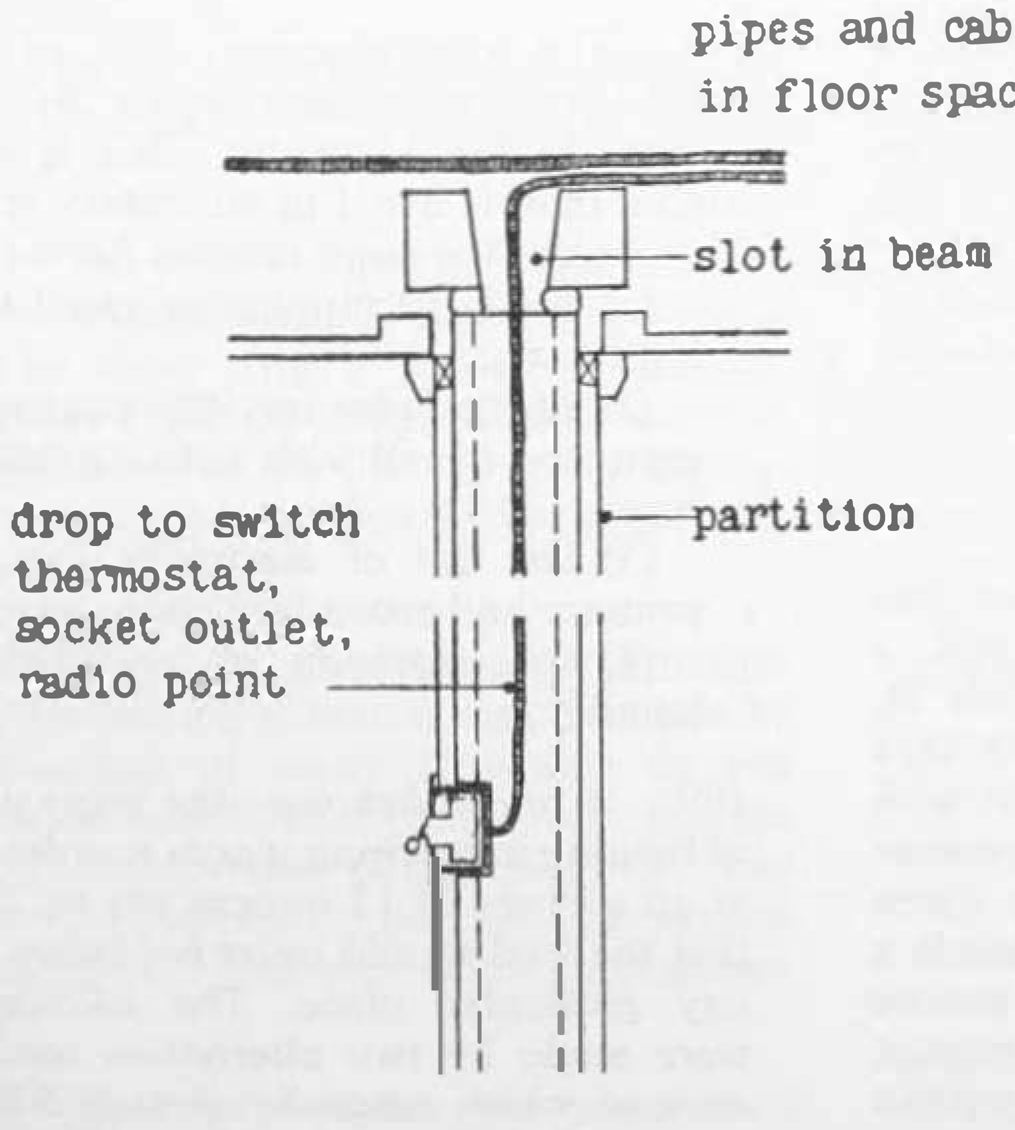


Diagram 36. BLIND BOX



PLAN



SECTION

Diagram 37. RELATIONSHIP BETWEEN STRUCTURE/PARTITIONS/SERVICES

SERVICES

Heating and hot water

184. Space heating is by the now well-established, re-circulated warm air method. Boilers are oil-fired.

185. Previously, the usual practice had been to provide hot or tepid water to wash-hand basins from a calorifier heated from the main space heating system in the winter and by immersion heater in the summer. Research by the Building Research Station, in association with the Ministry, suggested that both water and fuel could be saved by the use of spray taps delivering premixed electrically heated tepid water. At Arnold, this work was taken a step further and a standard range of three basins was devised, with spray taps delivering mixed water (at 100° F.) from a 3-gallon storage cylinder with a specially wound immersion heater. This arrangement was designed and tested by the Building Research Station, who will make a detailed study of its use when the school is occupied. The specially modified storage tank is placed immediately below the central basin, thus reducing pipe work to a minimum and obviating the need for a circulation system. (Plate 7).

186. A glazed, fireclay spray-basin was designed for the project; this, and a similar fitting in vitreous china (Plate 5), are now generally available. Two taps were also designed in co-operation with the manufacturers. The first is an ordinary screw down type delivering three pints of water per minute. The other is a timed, non-concussive type which can be adjusted to cut out at a predetermined number of seconds after being pushed down. The B.R.S. studiesat the Amersham School (see BUILDING BULLETIN No. 16*) suggested that 80 per cent of the pupils take less than 30 seconds to wash their hands. As an experiment the taps were therefore set to deliver pre-mixed water for 20 seconds, but they can be re-adjusted in the light of further studies.

Electrics

187. The work carried out by tbe electrical sub-contractor provides service to the three main groups of equipment, viz:

(1) artificial lighting;
(2) some water and space heating;
(3) general purpose socket outlets and connected power equipment.

These will be described in turn in the paragraphs which follow.

188. The total electrical load of these three items, after allowing for diversities in use, is 335 kilowatts. This is rather higher than is usual in secondary schools of this size; the main reasons for this are:

(1) the large number of small teaching rooms;
(2) the complex services required in a grammar school with a strong scientific bias;
(3) the use of electricity for some primary and secondary water heating;
(4) the provision of an all-electric laundry.

189. *Artificial lighting*—the general level of lighting in teaching spaces was designed at an *average* of 12 lumens per sq. ft., so that the level should never fall below 10 in any particular place. The calculations were made by two alternative methods, each of which naturally gives a different layout of fittings: the "lumen" method described in the E.L.M.A. Handbook and

*Ministry of Education Building Bulletin No. 16—
Development Projects: Junior School, Amersham, (H.M.S.O. 10s. 0d.)

the "split flux" method developed by the Building Research Station. The latter method takes account separately of the direct and indirect components of illumination. Both these methods were used alternatively in a number of identical rooms in the lower school, and the resulting illumination will be measured and compared.

190. Rooms in which activities needing better visual conditions take place were given a higher level of illumination, e.g., science laboratories (15 lumens per sq. ft.), technical drawing room (20 lumens) and needlework rooms (25 lumens). In addition, local lighting was used to supplement the general lighting at certain points, e.g., over wall-benching in individual study spaces, on workshop machines and on chalkboards.

191. In all, the artificial lighting accounts for 35 per cent of the total design load for electricity.

192. The light fittings are ceiling mounted, and include an existing type in acrylic sheet and a specially designed enclosed shade of coiled cellulose acetate. In addition, a number of other fittings were designed for particular situations. (Plates 1, 2 & 3).

193. *Water and space heating*—in designing the heating system it was found to be economical in many situations to use electrical immersion and unit storage water heaters (see paragraph 185). The electrical supply to the heating system amounts to 37 per cent of the total design load.

194. The *socket outlets* are rated at 13 amps. on a ring main system and have insulated plates, double pole switches and warning lights. Connected electrical power equipment includes an all-electric laundry in addition to the normal kitchen and teaching equipment. The electrical supply to these items amounts to 28 per cent of the total design load.

195. *Distribution*—the electrical supply is for the normal 215/240 volt, 3-phase A.C. supply at 50 cycles and is distributed by a series of section and local fuse boards. The supplies for power and lighting are combined up to the section boards and kept separate thereafter. The greater part of the installation is carried out in cable in which the live conductors are both insulated and sheathed in P.V.C., and in which is incorporated the earthing wire. Three-phase supplies and wiring in the boiler house are carried out in mineral insulated copper-covered cable.

196. All batten holders and ceiling roses are provided with a back plate, which satisfied the I.E.E. regulation requiring a flame-proof enclosure to the terminals. This enables an economy to be made by omitting the normal cast-iron box. The wiring is carried, throughout the school, in the space above the suspended ceiling. Drops in partitions to switches and wall-mounted accessories are made by drawing the P.V.C. cables down vertical ducts formed by the perforated concrete partition blocks (see paragraph 181). This is much cheaper than conduit in surface chases.

197. *Stage lighting*—the aim has been to achieve flexibility by providing as much wiring as possible together with a reasonable amount of equipment. This can be added to as school drama develops. There is a switchboard with fourteen 5 amp. circuits (with provision for dimmers) situated in a gallery in the stage wings. Four trapped floor socket outlets and three high level outlets have been provided on the stage itself and there are four front of house spots in the hall.

FINISHES

Floor finishes

198. In general, 4·5 mm. linoleum or 2 mm. hessian backed P.V.C. have been used. These combine a reasonable resilience with adequate toughness for normal use and are easily cleaned. Both are available in a useful range of marbled colours and reflectance factors.

199. On upper floors, where a 'quiet' floor is of even greater importance, studded rubber and $\frac{5}{16}$ in. t. and g. cork have been used. Cork has also been used in the assembly hall, staff rooms, library and music rooms where a quiet, warm and good looking floor was needed. It is finished with two coats of plastic seal.

200. The gymnasium has a pimpled P.V.C. tile—specially developed in Sweden for indoor tennis courts. It is stuck directly to the screed and therefore offers no resilience to impact. However, where specific areas of resilience are required, normal foam rubber agility mats will be used.

201. In order to compare the wearing and other characteristics of various finishes, several otherwise identical rooms have been given different floor finishes. In this way it will be possible to make direct comparisons between 4·5 mm. lino, 3·2 mm. lino, 3·2 mm. lino on underlay, studded rubber and 2 mm. hessian backed P.V.C. and between solid rubber, cork, linoleum and P.V.C. in circulation areas.

202. All ground floor finishes are protected by a D.P.M. which covers the entire site slab.

Painting

203. In teaching rooms, the finish is generally two coats of plastic emulsion paint. Walls in circulation spaces and other areas which were thought to be particularly vulnerable are finished in oil paint. Generally softwood is finished with oil paint and hardwood with plastic seal.

ACOUSTICS

Hall

204. In designing the hall acoustically it was impossible to satisfy fully the requirements both of large audiences and of small groups. The B.R.S. Digest recommends a reverberation time for speech and music in a general purpose school hall of between 1 and 1·25 seconds at 500 cycles per second, and it was decided, in view of the much more frequent use of the hall by smaller groups, that these conditions should obtain with a group of about thirty present. The reverberation time of 1·25 seconds at 500 cycles per second will in fact be particularly suitable for music. On the other hand it will be impossible to achieve this standard with an audience of 300–400 present, as the absorption of the audience will be twice that of the permanent surfaces. If required, additional absorption can be introduced by the use of curtains, and for a large audience reasonably "live" listening conditions will be obtained by the use of line source loudspeakers, which project a flat saucer of sound across the hall.

Music practice rooms

205. The problem here was to find a way of breaking up the reflected sound. One way would have been to set one of the walls, or the ceiling, askew, but this would of course, have meant disturbing the framework of the modular system. It was therefore decided to design the ceilings in the form of inverted pyramids having standard conditions for wall and ceiling fixing. The pyramids are built up of soft-wood framing faced with match-boarding and are 3 ft. 4 in. square. If it proves necessary, wall absorbent will be added later.

General

206. In general, care had to be taken to prevent sound from causing interference between rooms. The plastered concrete block partitions themselves have a good sound reduction value and the space between the ceiling and the roof deck has been interrupted by continuous bulk-heads (see paragraph 181). The trans-mission of sound through windows presented a problem only in the case of the practice rooms, as the main music room windows look on to the playing fields. The practice room windows, there-fore, are double glazed and have fixed lights only—ventilation being by means of acoustically baffled grilles in walls and ceiling.

RECORDS

207. Three aspects of the site work were recorded on charts as the work proceeded. These were:

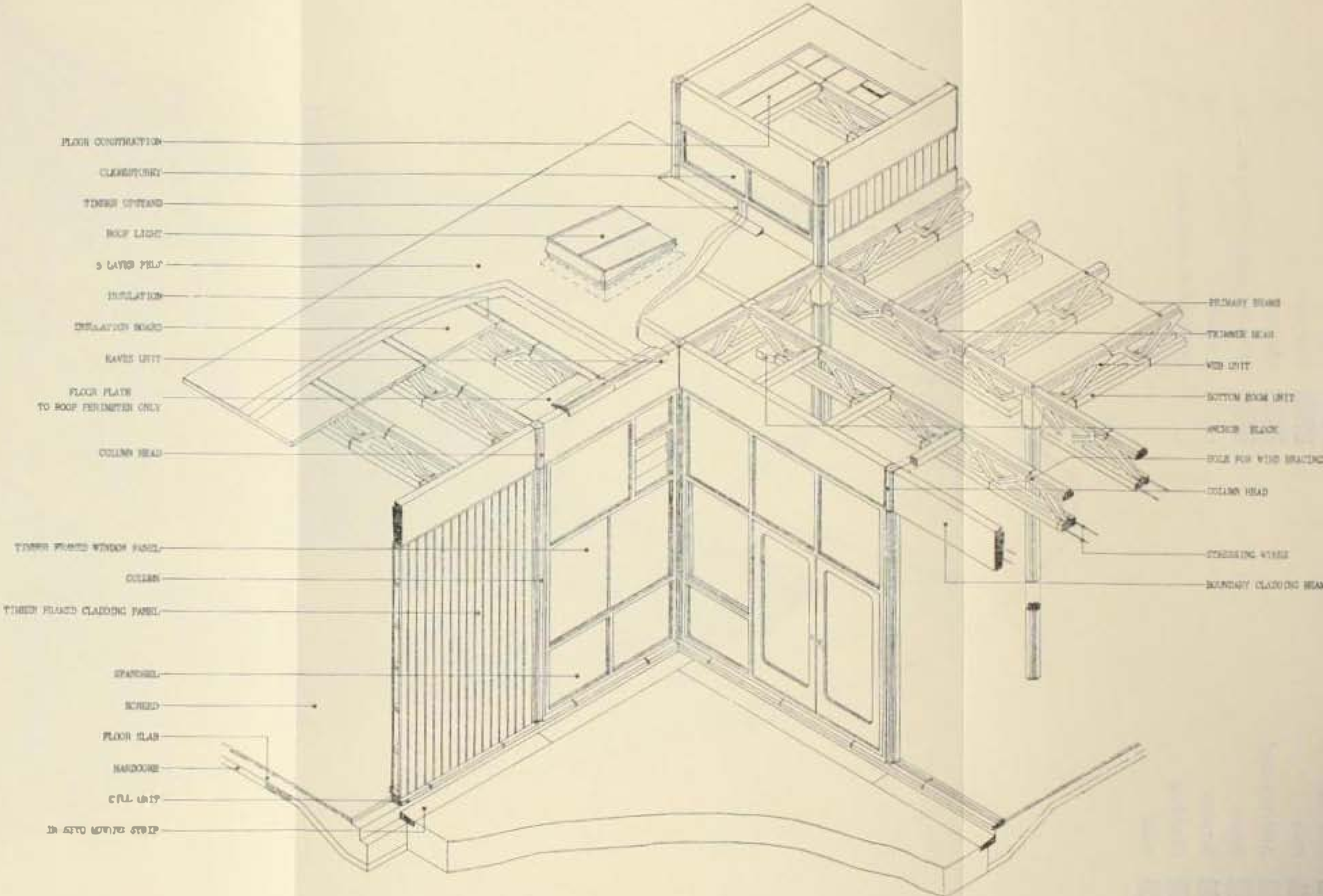
(a) *man-hours*—full records of time actually spent on every major site operation were kept by the clerk of works on a standard form. These were transferred to a "geological" chart (diagram 38) at monthly intervals. Certain operations, about which more detailed information was required in order to check assumptions made at design stage, were recorded in greater detail. Thus, for instance, the times spent on stressing components, erecting columns, erecting beams and placing floor plates were all kept separately (although they are grouped on the chart as "Frame"). It was assumed that productivity would be of the order of 60 sq. ft. per man-month, which was expressed as a notional line on the chart This assumption proved a little optimistic on this first job, but there is no reason why the level of output should not improve with experience;

(b) *cost*—the contractor's programme was expressed in cost of work to be completed (per week), and the monthly valuations were plotted against this;

(c) *progress*—the contractor's programme was "blocked-in" in the normal way as the work proceeded, each element having a subsidiary line representing estimated completion.

208. While these aids could not be regarded as conclusive in themselves—for example, the notional output figure proved too high, the valuations were never exact, and the estimation of completion could

not be precise—nevertheless, together they formed a useful guide to progress. This was particularly so when they all indicated the same degree of divergence from the programme. Records of this kind can, of course, be useful to those preparing to plan other projects. For instance, a geological chart often reveals areas where further energy might profitably be spent at the design stage in order to reduce man-hours on site: or, on the other hand, it might show where and how the site organisation or plant facilities might be improved.



ISOMETRIC OF STRUCTURE

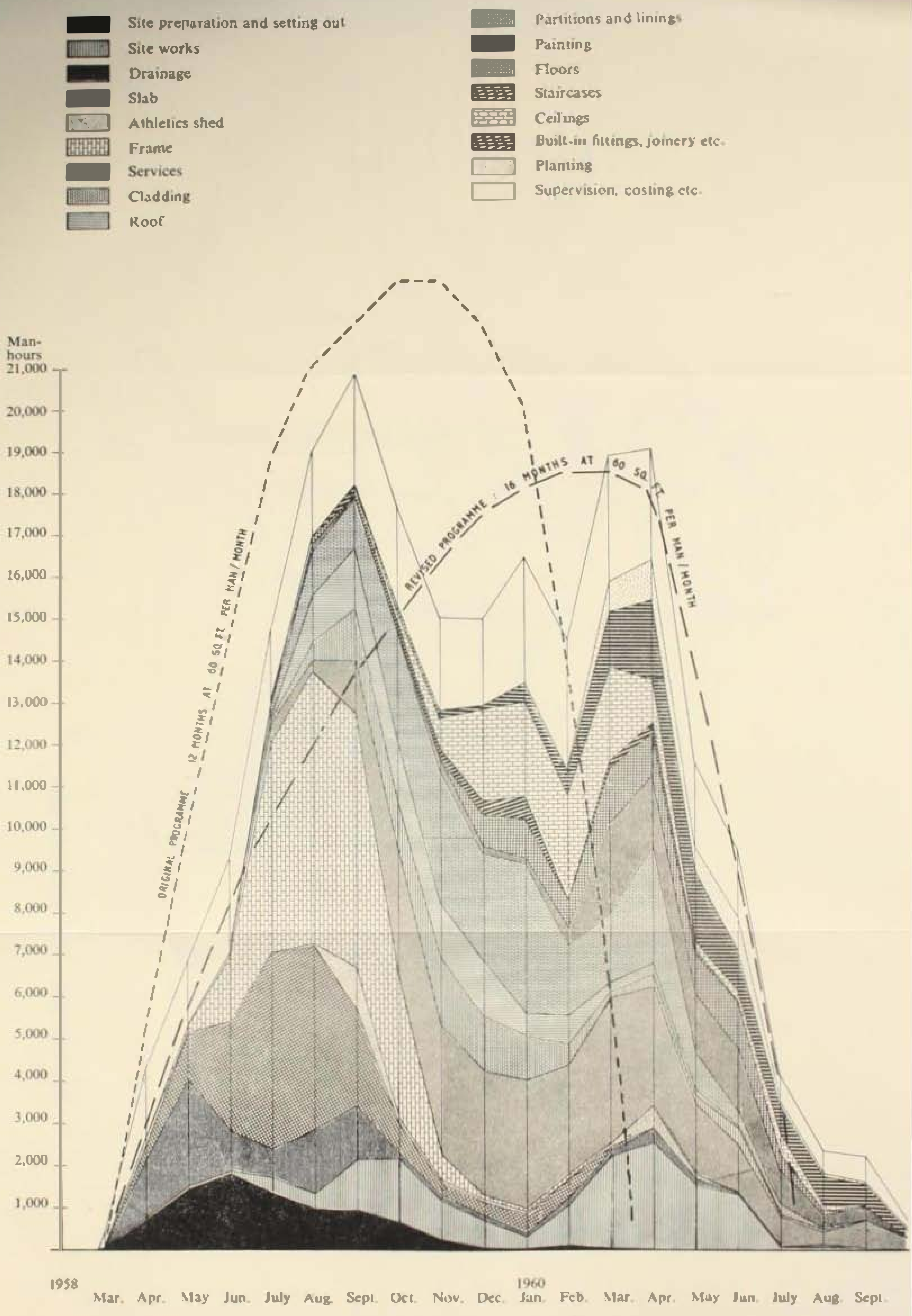


Diagram 38. "GEOLOGICAL" CHART OF BUILDING WORK

III. COST

Introduction

209. The Ministry's views about cost study have already been fully expressed in Building Bulletin No. 4 (second edition), but it will probably be useful to show how these known methods were applied in practice to this particular project.

The cost brief

210. The first discussion on cost took place in January 1956. At that time the nett cost limit for secondary schools was £264 per place, and the average for the country over the previous six months had worked out at about £247 per place. After studying a number of actual schools, it was thought that if the full nett cost allowance of £264 per place wereavailable, the best combination of area and cost for the Arnold school would be 72 sq. ft. per place at 73/4d. per sq. ft.

211. However, as one of the principal objectives at Arnold was the development of a system of construction which would be at least competitive with any other similar construction system on the market, it was decided that the design cost target for the school should be set at £252 per place, which was based on 72 sq. ft. per place at 70/– per sq. ft.

212. The Arnold school, as a four form-entry grammar school with a sixth form of 120 pupils, qualified for 816 cost places. At £252 per place, this gave a nett cost target of £205,632.

Choosing a contractor

213. For a development project of this nature, a firm had to be selected which would be willing to sponsor the design, development and testing of the system, and which would be able to spread the high initial cost over a number of future projects. It would also be responsible for the rest of the building work.

214. To allow as much time as possible for the development work, and to obtain the benefits of joint consultation on the building and cost problems, it was decided to select a firm at the beginning of the design stage. The firm not only had to be capable of carrying out successfully the development work and the work on site, but their price level for this negotiated contract would have to be acceptable to the client.

215. The methods adopted for investigating the contractor's price level have been fully described in the article "Negotiated Contracts" in the *Architects' Journal* of 4th December, 1958.

216. The cost investigation was just as vital to the firm as to the Development Group and the Local Education Authority, because it served to ensure that collaboration throughout the design and working drawings stages would not be wasted by unacceptably high costs at tender. It was understood by the selected firm that a contract for the Arnold project would depend eventually on a satisfactory tender based on a priced bill of quantities.

217. Cost planning (on the lines described in Appendix 12 of Building Bulletin No. 4 (second edition)) and cost checking (as described later) ensured cost control throughout the development of this project during the pre-contract period.

Targets for the structural elements

218. The structural elements were to form the core of the development work, and their final price was an important aspect of the undertaking. It was essential therefore to decide at an early stage the apportionment of the nett cost to the structural elements—namely, the frame, external walls, roof, roof lights, upper floor construction and staircases. As a result of close study of the cost analyses of two other schools, a target of 20/– per sq. ft. was fixed for the structural elements. This sum was 20 per cent below what had previously been spent on these elements in comparable systems. Table 6 compares the adjusted figures for the structural elements of a similar school with the proposed target figures for Arnold.

Table 6. Structural elements of known school
Area 53,883 sq. ft.
Costs per square foot of floor area

Cost Analysis Element	System components only				Complete element
	Items included	June '53	Jan. '56	Jan. '56 Less 20%	Jan. '56 Less 20%
FRAME	Columns Column heads Boundary, primary and secondary beams Supervision	9/2	10/1	8/1	8/1
EXTERNAL WALLS AND FACINGS	Cladding Flashings Expansion joints Supervision	3/5	3/9	3/–	4/4
ROOF CONSTRUCTION	Slabs, eaves and gutters Supervision	2/11½	3/3	2/7	4/3½
ROOF LIGHTS	Curbs Supervision	2½d.	2½d.	2d.	11d.
UPPER FLOOR CONSTRUCTION	Slabs Supervision	7½d.	8½d.	6½d.	6½d.
STAIRCASES	Stairs and enclosures Supervision	1/4½	1/6	1/2½	1/9
					19/11

The first cost plan

219. Normally, quantity factors are computed after receipt of the architect's sketch plans, and the first cost plan is prepared by using the information, adjusted as necessary, from one or more cost analyses of known jobs. In the case of Arnold, however, the first cost plan was prepared before the sketch plan was drawn. By using the quantity factors supplied by the architects (see Table 7) which indicated the areas and ratios which they considered they would probably work to on the sketch plan, and with the help of a cost analysis, the 70/– per sq. ft. was allocated in the manner set out in Table 8 (column A). The purpose of this exercise was to get a preliminary picture of the likely cost, allocated between the elements.

Subsequent cost plans

220. The second cost plan (see Table 8, column B) was prepared eight months later and was based on the architect's sketch plan.

221. The third cost plan (Table 8, column C) took into account further planning alterations, and formed the final cost plan for the project.

Cost targets

222. Table 9, Parts 1 and 2, are examples of the next step after the preparation of the cost plan. These cost targets were meant, broadly, to remind the architects of the items included, their approximate quantities and value.

Cost checks

223. As might be expected on a development project, the architect met problems on almost every element, and this involved checking the cost of alternative solutions.

Table 7. Quantity factors
Information supplied by Architect

Single storey floor area	34,250	
Two ,, ,, ,,	9,500	
Three ,, ,, ,,	15,000	
Total floor area	58,750	
Ratio solid walls / floor area	0·55	(altered to 0·50 for cost plan totalling 67/2·4d.)
Ratio windows and external doors / floor area	0·35	(altered to 0·29 ditto)
Area of roof	44,000 sq. ft.	
Area of roof lights	1,600 sq. ft.	
Area of upper floors	14,750 sq. ft.	
Total rise of stairs	108 f.r.	
Internal doors		
(a) single	110	
(b) double	14	
W.C. cubicles	40	
Sanitary fittings	215	
Gas points	90	
Electrical points		
(a) lighting	980	
(b) power	170	
Playground area	4,100 sq. yds.	

With a rough sketch and notes, the architect was able to convey his ideas to the contractor or manufacturer through the quantity surveyor, and at this stage, if the price was unsatisfactory, a new approach was possible with no serious consequences. If the price was favourable, he was, of course, able to go ahead with his design drawings.

224. When the design drawings for each element were completed, a cost check was made on approximate quantities. This was priced both by the quantity surveyor and by the contractor or manufacturer, and the figures compared. Here again, where cost difficulties arose, they were ironed out by discussion and examination of alternative solutions. The architect was

Table 8. Cost plans

ELEMENT	Cost per sq. ft. of floor area		
	A	B	C
	s. d.	s. d.	s. d.
1. Preliminaries and insurances	4 10·0	4 11·0	4 11·0
2. Contingencies	1 8·0	1 8·0	1 8·0
3. Work below ground level 4. Suspended ground floors	4 6·0	4 3·5	4 3·2
5. Frame	8 4·0	8 1·0	8 1·0
6. External walls	4 4·0	2 1·5	2 0·0
7. Windows and external doors (incl. glazing)	4 1·5	7 0·3	6 8·0
8. Roof construction	3 9·3	3 9·8	3 8·7
9. Roof lights	0 10·3	1 5·2	1 3·2
10. Upper floor construction	0 7·8	0 10·1	0 10·0
11. Staircases	1 6·1	1 0·8	1 0·6
12. Internal partitions	2 10·0	2 10·0	2 10·0
13. Internal doors	0 10·6	1 0·5	1 0·1
14. W.C. and cleaners' cubicles	0 3·0	0 2·8	0 2·8
15. Wall finishes	0 4·0	0 4·0	0 4·0
16. Floor finishes	4 5·0	4 5·0	4 5·0
17. Ceiling finishes	3 5·1	3 5·1	3 5·1
18. Decorations	1 9·0	1 9·0	1 9·0
19. Cloakroom fittings 20. Fittings 21. Furniture (built-in)	3 11·7	3 11·7	3 11·7
22. Plumbing (external, internal and sanitary fittings)	1 10·4	1 10·4	1 10·4
23. Gas installation	0 3·7	0 3·7	0 3·7
24. Electric installation	3 0·0	3 0·0	3 0·0
25. Heating installation	6 0·0	6 0·0	6 0·0
26. Ventilation	0 1·0	0 1·0	0 1·0
27. Drainage (nett cost)	1 5·0	1 5·0	1 5·0
28. External works (nett cost)	2 0·9	2 0·9	2 0·9
NETT COST	67 2·4	68 0·3	67 2·4
*Allowance for price and design risks	2 9·6	2 9·6	2 9·6
TOTAL	70 0·0	70 9·9	70 0·0

*See paragraph 59, Building Bulletin No. 4 (second edition) then able to go forward with working drawings, confident about the cost of what he was doing.

225. As cost checks were usually made when the architect required them, they extended over the whole design drawing period; some of the earlier ones, because of the inevitable pushing and pulling of the design as a whole, needed review at the end of this period.

Table 9. Examples of cost targets

1. **PARTITIONS**

Work included under this element

(i) Partitions
(ii) Glazed screens
(iii) Borrowed lights (if any)
(iv) Sound baffles in ceiling space above partitions

Money available

Cost target 2/10 per sq. ft. of floor area which is equivalent to (2/10 × 56,843 sq. ft.)		£8,053
The area of actual partitions or screens shown on sketch plan	=	3,365 sq. yds.
Allowing an area of 150 sq. yds. of glazed screens at £3	=	£450
Sound baffles	say	500
Borrowed lights	say	50
		£1,000
Amount remaining for partitions (£8,053 − £1,000)	=	£7,053
Area of partition to be provided (3,365 − 150)	=	3,215 sq. yds.
All-in cost/sq. yd. available		43/10½

2. **ELECTRICS**

Work included under this element

(i) Electric installation
(ii) Lighting fittings
(iii) Builders work in connection with (i) and (ii)

Money available

Cost target 3/- per sq. ft. of floor area which is equivalent to (3/- × 56,843 sq. ft.)	£8,526
This amount is for (i), (ii) and (iii) above.	
Assuming the same proportion of lighting fittings as for Woodlands School, i.e., 1:55·4 sq. ft. of floor area and the same level of cost = 9·1d. per sq. ft. of floor area which is equivalent to	£2,155
The cost of the builders work (including profit and attendance on sub-contract) on Woodlands School was equivalent to 1·6d. per sq. ft. of floor area. Assuming the same provision at Arnold the cost will be	£379
Therefore the amount available for the Installation (exclusive of lighting fittings, builder's work and external mains) is Therefore the amount available for the Installation (exclusive £8,526−(2,155+379) =	£5,992

Summary

	Cost/sq. ft.	*Total Cost*
(i) Electric installation	2/1·3	£5,992
(ii) Lighting fittings	9·1	2,155
(iii) Builder's work	1·6	379
	3/0·0	£8,526

226. A summary of all the final cost checks will be found in the centre column of Table 10.

Cost comments

227. It became obvious during the cost checking that certain elements which exceeded their target could not be reduced without affecting standards of quality or quantity. Whilst there were minor savings on several elements, there was an excess of 2/1d. over the cost target of 67/2·4d. This raised an important question of policy: whether standards should be reduced or the total cost target raised to a figure rather nearer the Ministry's cost limit.

Table 10. Comparative nett cost figures

Element	Costs per sq. ft. of floor area: Cost plan	Final cost check	Cost on Tender
	s. d.	s. d.	s. d.
1. Preliminaries and insurances	4 11·0	4 11·0	4 6·95
2. Contingencies	1 8·0	1 8·0	2 7·67
3. Work below ground floor level	4 3·2 (items 3–4)	3 9·3	4 3·29
4. Suspended ground floors		1·2	1·36
5. Frame	8 1·0	9 3·5	8 11·83
6. External walls	2 0·0	2 2·9	2 5·52
7. Windows and external doors	6 8·0	6 4·9	6 5·49
8. Roof construction	3 8·7	3 2·5	3 2·94
9. Roof lights	1 3·2	1 8·6	1 9·49
10. Upper floor construction	10·0	7·3	7·39
11. Staircases	1 0·6	7·2	7·79
12. Internal partitions	2 10·0	2 11·7	3 4·10
13. Internal doors	1 0·1	1 5·6	1 4·74
14. W.C. and cleaners' cubicles	2·8	3·1	2·52
15. Wall finishes	4·0	1·6	2·39
16. Floor finishes	4 5·0	4 2·8	4 0·05
17. Ceiling finishes	3 5·1	3 0·1	2 11·52
18. Decorations	1 9·0	1 4·9	1 8·23
19. Cloakroom fittings		2·0	2·71
20. Fittings	3 11·7 (items 19–21)	1 9·5	2 0·16
21. Furniture (built-in)		3 0·8	3 1·22
22. Plumbing (external, internal and sanitary fittings)	1 10·4	2 8·9	2 7·68
23. Gas installation	3·7	3·4	3·27
24. Electric installation	3 0·0	3 3·9	3 2·17
25. Heating installation	6 0·0	6 0·8	5 10·21
26. Ventilation	1·0	1·8	1·86
27. Drainage (nett cost)	1 5·0	1 1·4	1 5·33
28. External works (nett cost)	2 0·9	2 4·7	2 7·57
Total of items 1–28	67 2·4	69 3·4	71 1·45

228. It was decided that to avoid cutting standards, particularly on the "Fittings" elements, the total cost should be raised. There had been a steady increase in material prices since the preparation of the cost plan and a National Wage Award was expected before the receipt of the tender, so 2/3·8d. per sq. ft. of the 2/9·6d. included in the cost plan for price and design risks was left intact, and the self-imposed cost limit was raised from £252 to £257 8s. 0d. per place (or 72 sq. ft. per place at 71/6d. per sq. ft.).

229. The tender was negotiated on the basis of the cost checks that had been carried out during the design stage. The tender sum was £227,379 16s. 4d., of which £209,150 19s. 9d. was nett cost (equivalent to £256 6s. 3d. per place).

230. The complete cost analysis on tender is set out in Appendix 3. In it, the area of the school is given as 60,272 sq. ft., which was calculated in the manner prescribed on the Ministry's Form S.B.16, and it is from this figure that the area per place of 73·9 sq. ft. and the nett cost per sq. ft. of 69/5d. were computed.

231. The actual floor areas (within the inner face of the external walls) were:

(1) school (excluding athletics shed and covered ways) 56,829 sq. ft.

(2) athletics shed 8,430 sq. ft.

(3) covered ways 669 sq. ft.

232. To reconcile the figure of 60,272 sq. ft. with the total of these three figures, the games shed was shown on Form S.B.16 as equivalent to 1,600 sq. ft. of gymnasium, and the remainder of the difference was the allowances made for covered ways, covered areas and porches.

233. The comparative nett cost figures at cost plan, final cost check and tender stages are set out in Table 10. The cost per sq. ft. on tender, namely 71/1·45d., may be compared with the 70/– cost target or the 71/6d. revised target.

234. In conclusion, it should be emphasised that the £252 per place limit was self-imposed; it was always intended that it should be subject to review during the design stage. Although this review led to a new limit of £257 8s. 0d., the actual cost on tender was £256 6s. 3d. per place, which was £7 13s. 9d. below the Ministry's normal limit for secondary schools.

APPENDIX I

FURNITURE AND EQUIPMENT

Lower school classroom

Tables	15 dual locker* size C, 3 ft. 8 in. × 1 ft. 10 in.
	1 teacher's ,, E
Chairs	30 upright ,, C
	1 ,, ,, E
Wall-benches	20 ft. run, including heater cabinet
Movable shelves	26 ft. run, 7 in. wide
Pin-up board	24 sq. ft.
Chalkboard	40 sq. ft. in 3 panels, 2 hinged and 1 sliding
Storage	12 × 4 in. deep and 3 × 8 in. deep drawers in wall-bench
	8 cu. ft. under wall-benches
Blinds	venetian or woven plastic, to S. & W. windows
Electric point	1 × 13 amp. socket outlet

*1st year only: 2nd year has lockers

Middle school house

a. houseroom

Tables	10 dual, size D 3 ft. 8 in. × 1 ft. 10 in. } form 8 dining tables for 8
	6 dining extensions }
	1 teacher's size E
Chairs	64 upright ,, D
	1 ,, ,, E
Wall-benches	13 ft. run including heater cabinet
Movable shelves	24 ft. run, 7 in. wide
Pin-up board	24 sq. ft.
Chalkboard	11 sq. ft. mobile
Storage	4 × 4 in. deep and 1 × 8 in. deep drawers under wall-benches
	8 cu. ft. under wall-benches
Lockers	45 × 11 in. wide × 16 in. high × 9 in. deep
Window seat	16 ft. long
Curtains	white translucent cotton to S. & W. windows
Electric points	1 × 13 amp. socket outlet
	radio outlet

b. group room

Tables	20 single, size D, 2 ft. 6 in. × 2 ft. 0 in.
	1 teacher's ,, E
Chairs	20 upright ,, D
	1 ,, ,, E
Wall-benches	13 ft. run, including heater cabinet
Movable shelves	13 ft. run, 7 in. wide
Pin-up board	32 sq. ft.
Chalkboard	11 sq. ft. mobile
Storage	12 × 4 in. deep and 3 × 8 in. deep drawers under wall-bench
Curtains	white translucent cotton to S. & W. windows
Electric point	1 × 13 amp. socket outlet

c. house hall

Tables	2 hinged writing flaps, 2 ft 9 in × 1 ft. 8 in.
Chairs	2 upholstered arm, with book rests
Pin-up board	24 sq. ft.
Lockers	15 × 11 in. wide × 16 in. high and 9 in. deep
Coat and shoe racks	for 60

d. **house wardens' studies**

Tables	1 teacher's, size E
Chairs	1 upright ,, E
	2 ,, ,, D
Movable shelves	10 ft. run, 7 in. wide
Pin-up board	16 sq. ft.
Blinds	venetian
Coat peg	1
Electric point	1 × 13 amp. socket outlet

Library and 6th form

a. **general library**

Table	4 × 4 ft. × 3 ft. size D
	4 trapezoidal ,, D
	1 librarian's ,, E
Chairs	30 upright ,, D
	1 ,, ,, E
	5 upholstered arm chairs with book rests
Wall-benches	13 ft. run, including heater cabinet
Movable shelves	258 ft. run, 7 in. wide; 30 ft. run 12 in. wide
Pin-up board	48 sq. ft.
Storage	4 × 4 in. deep and 1 × 8 in. deep drawers under wall-benches separate store + 8 cu. ft. under wall-benches
Window seats	30 ft. run
Blinds and curtains	venetian blinds and black & white cotton curtains
Electric point	1 × 13 amp. socket outlet

b. **reference library**

Movable shelves	300 ft. run, 7 in. wide; 56 ft. run. 12 in. wide

c. **study library**

Tables	2 × 4 ft. × 3 ft. size D
	9 × 2 ft. 6 in. × 2 ft. ,, D
Chairs	20 upright ,, D
Wall-benches	6 ft. run, including heater cabinet
Movable shelves	90 ft. run, 7 in. wide; 18 ft. run, 12 in. wide
Pin-up board	24 sq. ft.
Curtains	white translucent cotton to S. windows
Electric points	7 × 2 amp. socket outlets, for desk lamps
	1 clock

d. **study 1**

Table	1 × 5 ft. × 3 ft. size D
Chairs	4 upright ,, D
Curtains	black & white cotton

e. **study 2**

Table	1 × 3 ft. 8 in. × 1 ft. 10 in. size D
Chairs	2 upright size D
Curtains	black & white cotton

f. **study 3**

Table	1 × 5 ft. × 3 ft. size D
Chairs	4 upright ,, D
	5 upholstered arm chairs, with book rests
Movable shelves	40 ft. run, 7 in. wide
Curtains	black & white cotton

g. 6th form room 1

Table	1 × 9 ft. × 5 ft. with semi-circular ends
Chairs	12 upright, size D
Movable shelves	60 ft. run, 7 in. wide
Pin-up board	32 sq. ft.
Curtains	black & white cotton
Electric point	1 × 13 amp. socket outlet

h. 6th form room 2

Tables	6 × 4 ft. × 3 ft. size D
Chairs	21 upright ,, D
Movable shelves	38 ft. run, 7 in. wide
Pin-up board	32 sq. ft.
Curtains	black & white cotton

i. 6th form room 3

Tables	11 × 2 ft. 6 in. × 2 ft. size D
Chairs	11 upright ,, D
Movable shelves	84 ft. run, 7 in. wide
Pin-up board	13 sq. ft. on back of chalkboard panels
Chalkboard	27 sq. ft. hinged and sliding
Curtains	white translucent cotton
Electric point	1 × 13 amp. socket outlet

j. 6th form common room

Tables	3 × 3 ft. × 3 ft. size D 4 trapezoidal ,, A 4 hinged writing flaps
Chairs	16 upright, size D 6 upholstered arm chairs, with book rests
Wall-benches	13 ft. run, including heater cabinet and sink
Movable shelves	24 ft. run, 7 in. wide
Pin-up board	24 sq. ft.
Storage	4 × 4 in. deep + 1 × 8 in. deep drawers under wall-benches + separate store
Lockers	120 × 11 in. wide × 30 in. high × 9 in. deep
Window seat	16 ft. long
Cupboard	6 ft. long × 2 ft. wide × 2 ft. deep
Curtains	white translucent cotton
Electric point	1 × 13 amp. socket outlet

General science laboratory

Tables	8 × 3 ft. 6 in. × 4 ft. 6 in. × 2 ft. 8 in. high
Stools	31
Benches	1 demonstration bench 10 ft. 6 in. × 3 ft. 6 in.
Wall-benches	70 ft. run, including heater cabinets
Pin-up board	24 sq. ft. + 32 sq. ft. on cupboard fronts
Chalkboard	90 sq. ft. roller
Storage	36 × 4 in. deep and 12 × 8 in. deep drawers under wall-benches 72 cu. ft. in wall-cupboard; 82 cu. ft. under wall-benches
Blinds	venetian blind, to give dim-out conditions
Electric points	2 × 13 amp. socket outlets 12 low voltage outlets
Gas points	7 outlets
Water points	1 hot and 5 cold
Drainage	5 sinks

Physics laboratory

Tables	5 × 3 ft. 6 in. × 4 ft. 6 in. × 2 ft. 8 in. high
Stools	21
Bench	1 island bench 3 ft. 6 in. × 4 ft. 6 in.
Wall-benches . . .	50 ft. run, including heater cabinet
Pin-up board . . .	48 sq. ft. + 16 sq. ft. on wall-cupboards
Chalkboard . . .	90 sq. ft. roller
Storage	24 × 4 in. deep and 10 × 8 in. deep drawers under wall-benches 32 cu. ft. in wall-cupboards; 32 cu. ft. under wall-benches
Wall frame and ceiling beam	
Blinds	black-out
Electric points . . .	2 × 13 amp. socket outlets 10 low voltage outlets
Gas points . . .	9 outlets
Water points . . .	1 hot and 5 cold
Drainage	5 sinks
Ventilation . . .	1 extract fan

Advanced physics laboratory

Stools	21
Benches	3 × 9 ft. × 3 ft. 6 in.
Wall-benches . . .	50 ft. run, including heater cabinet
Pin-up board . . .	32 sq. ft. + 24 sq. ft. on wall-cupboards
Chalkboard . . .	63 sq. ft. roller
Storage	36 × 4 in. deep and 17 × 8 in. deep drawers under wall-benches 48 cu. ft. in wall-cupboards; 38 cu. ft. under wall-benches
Blinds	for sun control only
Electric points . . .	5 × 13 amp. socket outlets 11 low voltage outlets
Gas points . . .	9 outlets
Water points . . .	1 hot and 3 cold
Drainage	3 sinks

Optics room

Stools	6
Wall-benches . . .	30 ft. run, including heater cabinets
Storage	16 × 4 in. deep and 4 × 8 in. deep drawers under wall-benches 28 cu. ft. under wall-benches
Blinds	black-out
Electric points . . .	1 × 13 amp. socket outlet 3 low voltage outlets
Gas points . . .	1 outlet
Water points . . .	1 cold
Drainage	1 sink
Ventilation . . .	1 ventilator

Mathematics

Tables	10 dual, 3 ft. 8 in. × 1 ft. 10 in. size D 1 teacher's size E
Chairs	20 upright ,, D 1 upright ,, E
Wall-benches . . .	10 ft. run
Pin-up board . . .	32 sq. ft.
Chalkboard . . .	63 sq. ft. roller
Storage	8 × 4 in. deep and 2 × 8 in. deep drawers under wall-benches 8 cu. ft. under wall-benches map chest

6498

Ceiling beam and wall frame	
Electric point	1 × 13 amp. socket outlet 1 low voltage outlet
Gas point	1 outlet
Water point	1 cold
Drainage	1 sink

Chemistry laboratory

Stools	21
Benches	1 × 3 ft 6 in × 12 ft. 1 × 3 ft. 6 in. × 9 ft. 2 × 3 ft. 6 in. × 6 ft.
Wall-benches	43 ft. run, including heater cabinets
Pin-up boards	48 sq. ft. + 24 sq. ft. on wall-cupboards
Chalkboard	90 sq. ft. roller
Storage	28 × 4 in. deep and 7 × 8 in. deep drawers under wall-benches 48 cu. ft. in wall-cupboard; 42 cu. ft. under wall-benches
Fume cupboards	3
Electric points	3 × 13 amp. socket outlets
Gas points	13 outlets
Water points	1 hot and 13 cold
Drainage	4 sinks and 9 dilution pots

Advanced chemistry laboratory

Stools	20
Benches	2 × 3 ft. 6 in. × 9 ft. 2 × 3 ft. 6 in. × 6 ft.
Wall-benches	50 ft. run, including heater cabinets
Pin-up board	32 sq. ft. + 24 sq. ft. on wall-cupboards
Chalkboard	63 sq. ft. roller
Storage	32 × 4 in. deep and 11 × 8 in. deep drawers under wall-benches 48 cu. ft. in wall-cupboards; 52 cu. ft. under wall-benches
Blinds	for sun control only
Fume cupboard	1
Electric points	6 × 13 amp. socket outlets 3 low voltage outlets
Gas points	13 outlets
Water points	1 hot and 13 cold
Drainage	3 sinks and 10 dilution pots

Balance room

Wall-benches	23 ft. run, including heater cabinets
Blinds	for sun control only

Biology laboratory

Tables	6 × 4 ft. × 4 ft. × 2 ft. 8 in. high
Stools	21
Wall-benches	45 ft. run, including heater cabinets
Pin-up board	24 sq. ft. + 32 sq. ft. on wall-cupboards
Chalkboard	90 sq. ft. roller
Storage	40 × 4 in. deep and 13 × 8 in. deep drawers under wall-benches 56 cu. ft. wall-cupboards; 18 cu. ft. under wall-benches
Blinds	black-out
Electric points	4 × 13 amp. socket outlets 9 low voltage outlets

Gas points	3 outlets
Water points	4 cold
Drainage	4 sinks
Ventilation	1 extract fan

Lecture demonstration room

Fixed seating and book rests for 48

Bench	1 demonstration bench, 3 ft. 6 in. × 20 ft. 6 in.
Wall-benches	13 ft. run, including heater cabinets
Movable shelves	24 ft. run, 7 in. wide
Pin-up board	24 sq. ft.
Chalkboard	90 sq. ft. roller
Blinds	black-out
Electric points	3 × 13 amp. socket outlets 1 low voltage outlet 1 radio and T.V. outlet
Gas points	1 outlet
Water point	1 cold
Drainage	1 sink
Ventilation	1 extract fan

Preparation room (1 of 4)

Stools	2
Wall-benches	33 ft. run, including heater cabinets
Pin-up board	16 sq. ft. on wall-cupboards
Storage	24 × 4 in. deep and 6 × 8 in. deep drawers under wall-benches 40 cu. ft. in wall-cupboards; 34 cu. ft. in wall-benches
Electric point	1 × 13 amp. socket outlet
Gas point	1 outlet
Water point	1 cold
Drainage	1 sink

APPENDIX 2

LAUNDRY

The Alternatives

1. The Local Education Authority proposed to issue each pupil with gym. and games kit. After use, responsibility for washing the kit would either have to lie with the pupil (and his family) or with the Authority. The following alternatives presented themselves:

(1) to let the kit be washed at home, storage at school being by means of kit hangers;

(2) to use local laundries;

(3) to install a small, self-contained laundry at the school.

2. Some of the advantages and disadvantages of each of these systems are set out in the paragraphs which follow.

Kit Hangers

3. This method is quite expensive to install but costs nothing to run. After the kit has been used, its progress to the wash is uncertain On the washday, the dirty kit has to be collected from the changing-room at the end of the afternoon. Sometimes the pupil might carry the dirty kit with him to avoid returning to the changing-room. Some kit is certain to be washed infrequently and left in places other than the changing-room (most probably in the pupil's locker). Although the staff can urge the pupils to launder the kit regularly, this system does not really ensure, or encourage, cleanliness.

Local Laundries

4. So far as the pupils are concerned it does not matter where the kit is laundered so long as clean sets are readily available. But so far as the school generally is concerned there must be part time staffing, and space in the school to store and issue the clean kit and to store and despatch the dirty kit.

5. The work can be put out to contract in two ways—either to commercial laundries or to non-profit-making authorities (such as hospitals, public baths and workhouses) which happen to have spare capacity. In either case the number of spare sets of kit would have to be carefully related to the frequency of deliveries. In comparing prices, care must be taken that the cost of collection and delivery is included.

Small Laundry Unit

6. This solution, in addition to ensuring a high standard of kit cleanliness, leaves the school independent of commercial laundries and the delivery problems they might entail.

7. These advantages must, however, be weighed against the cost of providing, staffing and maintaining the laundry.

8. It was envisaged, at Arnold, that kit, sorted out by sizes, would be issued from the school laundry, and each pupil would collect a set on the way to the changing-room. A monitor, or the laundry assistant, would lay out the necessary number of towels in each changing-room. It would be the responsibility of the pupil to take the used towel and kit out of the changing-room and return them to a laundry tub parked in the corridor. This would then be taken to the school laundry.

9. A particular problem for the small laundry unit is that it must run without a relief machine (on grounds of expense). This probably means that an insurance policy would have to be taken out so that if there is a breakdown, the cost of commercial laundering can be recovered. Although the machines are simple to operate, they are mechanically complex, and the risk of breakdown must be considered in relation to local repair facilities. An obvious answer to this problem is for the authority to establish a central laundry serving several schools, where it would be economic to provide relief machines and also to have a technical staff capable of carrying out repairs. This arrangement is outside the scope of this Appendix.

10. Another disadvantage of a small unit is that, in order to avoid excessive capital cost, electricity is more or less obligatory as a method of boosting washing machine temperature and tumbler drying. Electrical laundry equipment tends to need more frequent maintenance than a steam system.

Technical implications of a self-contained laundry

11. It has already been explained (in paragraphs 124–127 of the Bulletin) that the

decision at Arnold was in favour of a self-contained laundry unit. The implications of this decision in terms of machines and washing methods are now discussed.

12. A laundry installation to deal with the normal school load would comprise:

(1) a washing machine

(2) a hydro extractor

(3) a drying tumbler.

Washing machine

13. Commercially, a washing machine is usually first supplied with water at 160°–180°F, which, to sterilise the garments, is then "boosted" to over 200°F. Most machines, in this country, are designed to use steam for this boost, but there are a few standard, or adapted, machines which use electricity.

14. These will, however, work with a completely cold supply, although the consumption of electricity, and the time taken in washing, would then obviously increase. A normal consumption of water would be about 2½ gallons per lb. of dry weight.

15. This type of machine is usually more expensive to maintain than those which are steam injected, mainly because the immersion heater is a more likely source of trouble than the simple steam valve.

16. Nearly all types of washer may be fitted with continuous rinsing devices which shorten the total washing time by avoiding the stop-start technique and the manual valve operation of the standard machine. The inclusion of this device usually adds some £40–50 to the total cost of the washer.

17. Whenever possible, laundry machinery should be connected to the town drain. The waste, with detergents or soap and soda in solution, prevents bacterial action in a septic tank. If the septic tank has to be used, then pre-treatment tanks have to be installed to deal solely with this waste.

Hydro extractor

18. There are two main types of machine available in this country:

(1) those with motors placed away from the revolving basket, which are belt driven —this arrangement is expensive in floor space;

(2) more recent designs have included the motor beneath the basket, housing both units in one casing. The insurance companies regard the revolving basket as a separate risk from the rest of the machine.

Drying Tumbler

19. Tumblers are available which are heated by steam, gas and electricity. The action of revolving partially dried clothes and subjecting them to a stream of hot air, makes this method suitable only for cottons, If woollens are treated in this way, they shrink and get badly worn by the mechanical action. Convection drying, which woollens need, is a slow process and takes up a large floor area. If wool can be avoided in school kit, the more economic tumbler can be used.

20. The tumbler has a hot air discharge which should be carried to the open air, unless the heat can be put to some alternative use.

21. Steam coil heating requires the least maintenance of the three types. The electrically heated machine uses approximately 16 kw. per hour but is still the best alternative to steam. While in this country electrical heating has been rejected as a commercial proposition, the continental manufacturers have many years of experience with this method. Several British firms are prepared to adapt their standard machines to electrical boosting.

22. Gas machines have a high fire risk because of the difficulty of isolating the fluff from the gas burners, and the added disadvantage of needing a flue for the gas exhaust.

Washing Methods

23. The water usage figure of approximately 2½ gals. per lb. dry weight given previously is based on the laundry practice of one or two suds, using soap and soda or detergents Detergents which give a high foam result should be avoided. There is available a special low foam detergent which is more suitable where the waste disposal is through a septic tank.

24. The American practice of low-temperature washing relies on the principle of high pasteurisation and frequent changes of water which give progressive dilution of infection. Sharp changes in pH. provide the worst possible conditions for bacterial life. It allows the washing process to be carried out at 150°F instead of 200°F. and over, and still results in a sterile article. This method is at present being studied by the Institute of British Launderers, before recommendations are

made to the commercial laundries in this country. A report will ultimately be available. It is not possible to give an accurate cost picture of this method, but before it could be adopted for school laundries some of the following points would have to be considered:—

(1) there would be less justification for steam use, as the washing machine would no longer need boosting. The steam would then only be needed to serve the drying tumbler;

(2) with the all-electric machines the washer would need no additional boosting, but the consumption of the tumbler would remain the same;

(3) because of the increase in the number of suds and rinses, as well as the addition of the sour bath the overall washing time is likely to be considerably lengthened;

(4) hot and cold water consumption would be increased between 30 and 50 per cent over normal practice. If the septic tank method of disposal were used its capacity would have to be doubled;

(5) the fabric life is shortened by the acid concentrations and the prolonged mechanical action of this method.

Capital Costs

25. In order to provide a comparison of costs between the methods examined above, the following rough estimates have been made. (In each case a daily load of 519 lbs. dry weight of washing, made up of 351 lbs. coloured and 168 lbs. white, was assumed);

(1) no laundry, storage by means of metal hangers and racks—£3,720;

(2) use of local laundry—£400 for storage;

(3) school laundry:

(a) using steam equipment to boost washing temperatures and heat for tumbler—£3,150;

(b) using electrical boosting and heating—£2,764.

26. The above prices include the relevant floor area priced at 70/- per sq. ft. together with an allowance for builder's work and services.

27. The actual equipment used at Arnold, with prices, was:

(1) 46-lb. electrically boosted washing machine £595

(2) 16 in. hydro extractor . £195

(3) Electric drying machine . £290

(4) Two dry work trolleys, one wet work trolley £70

Running Costs

28. It will not be possible to give actual running costs of the installation at this school until it has been in full operation over a period. When a statement is available, however, it should include the following items:—

(1) cost of heating water

(2) electricity consumption

(3) machine depreciation

(4) maintenance

(5) washing powders

(6) insurance

(7) staffing.

APPENDIX 3 COST ANALYSIS

Type of school	4 form entry mixed selective secondary with sixth form of 120.		
Number of cost places	816	Nett cost	£209,150 19s. 9d.
Floor Area	60,272 sq. ft.	Nett cost per place	£256 6s. 3d.
Area per place	73·9 sq. ft.	Nett cost per square foot	69s. 5d.
Tender date	27th February, 1958	Gross cost Building Contract	£227,379 16s. 4d.
Market conditions	Average prices by negotiation.	Playing Fields	9,466 2s. 7d.
		Private Sewer	662 1s. 2d.
			£237,508 0s. 1d.

Element	Cost per sq. ft. s.	d.	Total Cost £	s.	d.
Note: Floor Area for items 1–28=56,829 sq. ft.					
1. Preliminaries, preambles and insurances	4	6·95	13,011	0	0
2. Contingencies	2	7·67	7,500	0	0
3. Work below ground floor level	4	3·29	12,145	5	7
4. Suspended ground floors		1·36	321	3	10
5. Frame	8	11·83	25,535	1	2
6. External walls	2	5·52	6,990	4	1
7. Windows and external doors	6	5·49	18,350	1	10
8. Roof construction	3	2·94	9,220	2	3
9. Roof lights	1	9·49	5,089	8	5
10. Upper floor construction		7·39	1,748	17	11
11. Staircases		7·79	1,843	12	2
12. Internal partitions	3	4·10	9,496	8	8
13. Internal doors	1	4·74	3,965	0	9
14. W.C. and cleaners' cubicles		2·52	597	10	3
15. Wall finishes		2·39	565	3	7
16. Floor finishes	4	0·05	11,378	5	6
17. Ceiling finishes	2	11·52	8,410	0	8
18. Decorations	1	8·23	4,790	19	1
19. Cloakroom fittings		2·71	641	16	9
20. Fittings	2	0·16	5,721	19	9
21. Furniture (built-in)	3	1·22	8,814	16	7
22. Plumbing	2	7·68	7,501	5	7
23. Gas installation		3·27	774	10	0
24. Electric installation	3	2·17	9,038	10	0
25. Heating installation	5	10·21	16,624	16	11
26. Ventilation		1·86	441	0	1
27. Drainage (nett cost)	1	5·33	4,102	18	10
28. External works (nett cost)	2	7·57	7,475	15	7
Total of items 1–28	71	1·45	202,095	15	10
29. Covered ways. Area 669 sq. ft.	56	8·00	1,895	3	11
30. Athletics shed. Area 8,430 sq. ft.	12	2·9	5,160	0	0
NETT COST			**£209,150**	**19**	**9**

Element	Cost/sq. ft. floor area s. d.	Specification
1. Preliminaries, preambles and insurances	4 6·95	
2. Contingencies	2 7·67	
3. Work below ground floor level .	4 3·29	Strip surface 8 in. deep. Excavate to reduce levels. Make up levels with earth. 3 in. shale beds. 5 in. concrete floor slab reinforced with Ref. 124 fabric. Concrete edge beam reinforced with rods. 6 in. thick concrete retaining walls. Concrete steps and column bases. 2 coat bituminous damp proof membrane. Bituminous paint on plinth.
4. Suspended ground floors Area 666 sq. ft.	1·36	Side aisles to assembly hall consisting of 5 in. reinforced concrete suspended floor on dwarf bearer walls.

Floor area in single storey	29,531
Floor area in two storey	8,589
Floor area in three storey	18,709
Bearing pressure 8–9 tons	
Nature of site	Marly clay over hard red marl at depths of 3–5 ft.
Site levels	Slope of 1:13
Water table	Not encountered in trial holes
Depth of bearing strata	Not applicable

	Element	Cost/sq. ft. floor area s. d.	Specification
5.	Frame	8 11·83	3 ft. 4 in. modular pre-cast concrete frame with 6 in. × 6 in. pre-stressed columns at 6 ft. 8 in. and 10 ft. 0 in. centres on the perimeter, post-stressed self-faced slab boundary beams 1 ft. 7 in. deep × 6 ft. 8 in. and 10 ft. 0 in. long, post-stressed lattice main beams 1 ft. 6 in. deep and spanning up to 46 ft. 8 in., and post-stressed lattice trimmer beams 1 ft. 8 in. deep and spanning 6 ft. 8 in. and 10 ft. 0 in. The main beams are spaced at 3 ft. 4 in. centres.

	Primary Spans 3 ft. 4 ins. Modules	Loadings lbs./sq. ft.	Area Sq. ft.
Single Storey		Roof 23	30,102 (includes 571 sq. ft. in covered ways)
Craft block	6, 8 & 12		
Middle school	7 & 9		
Aisles to hall	9 & 6		
6th common	5		
Music rooms	8		
Changing	10		
Generally 10 ft. 10 in. Floor—roof			
Stage	14		
Boiler room	7		
15 ft. 0 in. Floor—roof			
Gymnasium	12		
Hall	12		
17 ft. 6 in. Floor—roof			
Two Storey		Floor 90 Roof 23	8,931 (includes 342 sq. ft. in way under)
Administration and library, etc.	8, 11 & 13		
20 ft. 0 in. Floor—roof			
Three Storey		Floor 90 Roof 23	7,637 (includes 772 sq. ft. in covered space)
Lower school	6, 9 & 12		
30 ft. 0 in. Floor—roof			
Science block	7, 9 & 12		11,844
32 ft. 6 in. Floor—roof			
			58,514

	Element	Cost/sq. ft. floor area s.	d.	Specification
6.	External walls . . . . . Ratio $\frac{\text{solid wall}}{\text{floor area}} = 0{\cdot}215$	2	5·52	4¾ in. thick overall timber prefabricated cladding units ranging in size from 6 ft. 2 in. × 1 ft. 8 in. to 9 ft. 6 in. × 9 ft. 2 in. consisting of softwood framing faced externally with 1 in. softwood boarding treated with two coats coloured preservative and internally with ⅜ in. asbestos wallboard over an insulating lining of building paper and aluminium foil. The units are fixed between columns and have 2¾ in. girth P.V.C. metallic silver flashing at top and bottom edge of cladding units. 1,300 sq. yds. Also included under this element heading are roof upstand units consisting of softwood framing covered externally with ½ in. plywood (32 sq. yds.) and 4¾ in. hollow concrete block walling (24 sq. yds.)
7.	Windows and external doors . Ratio $\frac{\text{windows and door area}}{\text{floor area}} = 0{\cdot}385$	6	5·49	Softwood prefabricated window and door frame units, plate glass sliding windows and glass louvres (both including glass). 3 No. single and 1 No. double flush and 8 No. single and 38 No. double framed doors including all ironmongery (generally Swedish with satin nickelsilver finish), galvanised steel thresholds. P.V.C. metallic silver flashings. Spandrel panels faced externally with ¼ in. compressed asbestos cement sheet and internally with ⅜ in. asbestos wallboard over an insulating lining of aluminium foil.
8.	Roof construction . . . . Area = 39,942 sq. ft.	3	2·94	2 in. thick compressed strawboard in 3 ft. 0 in. × 12 ft. 0 in. slabs spanning between beams at 3 ft. 4 in. centres and with steel tees at edges of slabs. 3,213 sq. yds. 1½ in. thick pre-cast concrete slabs as windbracing on perimeter. 944 sq. yds. 3 in. concrete in situ roof to boiler house. 16 sq. yds. 3 in. × 10 in. precast concrete eaves capping. 2,800 ft. run. Expansion joints and trimming around vents. Balustrading to balcony. 54 ft. run.
9.	Roof lights . . . . . No. 215	1	9·49	2 ft. 7¾ in. × 2 ft. 7⅝ in. × 2 ft. 0¾ in. deep metal roof lights. Opening gear to 30 No. Glazing, softwood linings and curbs.

Element	Cost/sq. ft. floor area s. d.	Specification
10. Upper floor construction . . Area 15,511 sq. ft.	7·39	3 ft. 0 in. × 1 ft. 1 in. × 1½ in. thick precast concrete slabs. Expansion joints.
11. Staircases . . . . . Number / Rise / Width 1 / 10 ft. 0 in. / 4 ft. 0 in. 1 / 20 ft. 0 in. / 4 ft. 0 in. 1 / 21 ft. 8 in. / 4 ft. 0 in. 1 / 24 ft. 2 in. / 4 ft. 0 in.	7·79	Precast concrete stairs and landings. Wrought iron balustrades and hardwood handrails. 536 ft. run.
12. Internal partitions . . .	3 4·10	4½ in. hollow concrete blocks. 2,973 sq. yds. 6 in. Ditto 289 sq. yds. 3 in. Ditto as sides to heater cabinets. 25 sq. yds. Gypsum plastering 5,341 sq. yds. Timber stud partition faced with asbestos wallboard. 43 sq. yds. Softwood framed bulkheads faced with ⅜ in. asbestos wallboard. 66 sq. yds. Sound reducing bulkheads in ceiling space:— 3 in. concrete blocks 155 sq. yds. 4½ in. Ditto 19 sq. yds. 1½ in. woodwool 233 sq. yds. Softwood screens glazed with georgian wired polished plate glass 171 sq. yds. Expansion joints.
13. Internal doors . . . . Single 124 flush 8 framed Double 6 flush 23 framed	1 4·74	Flush doors to B.S.459 part 2a faced both sides with utile veneered plywood. Framed doors to B.S.459 part 1 in utile. Softwood frames and fanlights. Glazing:— In door panels 874 sq. ft. In fanlights 1,078 sq. ft. Ironmongery—Swedish with satin nickel silver finish.
14. W.C. and cleaners' cubicles. . Cubicles 18	2·52	Partitioning consisting of softwood framing with ⅜ in. plywood infilling. Flush doors and ironmongery.
15. Wall finishes	2·39	Asbestos cement sheet wall lining 589 sq. ft. P.V.C. splashbacks 284 sq. ft. Tile splashbacks 51 sq. yds. Israelie gaboon faced plywood wall panelling 160 sq. ft. Maarud mahogany panels as wall lining 291 sq. ft.

Element	Cost/sq. ft. floor area s. d.	Specification	
16. Floor finishes	4 0·05	P.V.C. in situ	562 sq. yds.
		P.V.C. tiles	275 sq. yds.
		Rubber tiles	34 sq. yds.
		Studded rubber tiles	591 sq. yds.
		Linoleum	1,362 sq. yds.
		Vinyl asbestos tiles	22 sq. yds.
		P.V.C. sheet	1,459 sq. yds.
		Cork tiles	1,005 sq. yds.
		Quarry tiles	291 sq. yds.
		Rubber nosings	1,100 ft. run.
		Cement and sand beds.	
		Building paper under quarry tiles.	
		Softwood skirting	7,705 ft. run.
		Quarry tile skirting	703 ft. run.
		Terraced flooring	45 sq. yds.
		Fibre link mats and metal matwell frames	9 no.
17. Ceiling finishes	2 11·52	Fibrous plaster in panels mainly 3 ft. 4 in. × 3 ft. 4 in., 36% plain, 64% sound-absorbing	5,688 sq. yds.
		Match-boarded panels	130 sq. yds.
		Softwood cornices	10,313 ft. run.
18. Decorations	1 8·23	Internally. Walls: 3 coats emulsion or primer and 2 coats oil colour. Selected ceilings: 2 coats emulsion. Softwood roof-lights, windows, doors, screens and W.C. cubicles and fittings: K.P.S. and 2 coats oil colour. Softwood skirtings: 2 coats of stain. Hardwood fittings and wall finishes: 2 coats of plastic seal. Metal fittings: primer and 2 coats oil colour. Externally. Softwood windows and doors: K.P.S. and 2 coats oil colour.	
19. Cloakroom fittings	2·71	Coat racks and shoe boxes in No. 18 hardwood units 6 ft. 2 in. long × 2 ft. 1½ in. wide with coat racks over.	
		Hat and coat hooks	No. 720
20. Fittings	2 0·16	Storage shelving	364 sq. ft.
		Storage racks	1.218 sq. ft.
		Wood and metal storage racks.	
		Games storage racks and pegs.	
		Hall stores and cupboards.	

Element	Cost/sq. ft. floor area s. d.	Specification
		Balustrade to steps. Stage suspension gear. Display cills. Window seats. Draining boards. Kitchen hatches, stacking units. Servery units, larders and stores, screens and worktops. Central store shelving, vegetable preparation units. Cold room. Laundry hatch, kit dispenser. Changing room benches. Laundry equipment value £1,150. Sundry hatches and small fittings. Curtain tracks, proscenium curtain fittings, hand lift, window guard bars, removable kitchen draining boards and hinged writing tables. Fix only kitchen equipment.
21. Furniture (built-in) . . .	3 1·22	Lockers and stands — No. 661 Wall-benching — 982 ft. run. Working tops Pin-up boards — 235 sq. yds. Roller chalkboards — No. 15 Sliding chalkboards — No. 10 Mobile chalkboards — No. 13 Adjustable shelving — 1,426 ft. run. Book and magazine racks — No. 3 Fume cupboards — No. 3 Damp cupboard — No. 1 Fix only fire fighting equipment, toilet roll holders, and mirrors and gym equipment.
22. Plumbing . . . . . . Type Supply: Drinking water from main. Remainder from storage. Location of Fittings: Dispersed. Storage Capacity: 9,076 galls. Nature of water: Hard.	2 7·68	External 3 in. aluminium alloy rain water goods. Pipes 254 ft. run. Preformed soakers etc. Value £285 12s. 0d. = 1·21d. sq. ft. of floor area. Internal. Water storage and pumps. Light gauge copper piping for cold drinking main to No. 3 kitchen and hot and cold down services. Preformed wastes in copper and acid resisting wastes. Soil and waste stacks in galvanised steel. Value £4,067 15s. 7d. = 1/5·18d. sq. ft. of floor area.

	Element		Cost/sq. ft. floor area s. d.	Specification
	Fireclay fittings No. 155 Dilution pots No. 24			Sanitary fittings. White glazed fireclay, with chromium-plated fittings chemical stoneware dilution pots and laboratory fittings. Metal sink stands. Value £3,147 18s. 0d. = 1/1·29d. sq. ft. of floor area.
23.	Gas installation No. 64 points		3·27	Mild steel tubing.
24.	Electric installation		3 2·17	P.V.C. wiring. Lighting fittings and clocks. Electric water heaters. Fire alarm system. Electriccontrols to heating system (No. 58 heater cabinets). Stage lighting P.C. £150. Radio and television wiring P.C. £89. Low voltage supply P.C. £460. Lightning conductor P.C. £150. Telephone installation. Laundry wiring.
	Nature of Supply	240 volt 3 phase 50 cycles/sec.		
	Lighting requirements	Minimum 10, Average 15 lumens per sq. ft. on working plane in classrooms		
	Lighting points	1,154		
	Clock points	18		
	Power points:—			
	13 amp. single sockets	128		
	13 amp. twin sockets	10		
	30 amp. single sockets	4		
	Water heaters	74		
	Extract fans	12		
	Mixing machines	3		
	Fire alarm bells	14		
	Fire alarm pushes	17		
25.	Heating installation		5 10·21	Thermostaticallycontrolled warmairsystem of heating: hot water circulated by pumps from oil fired boilers to heater exchange units. Hot water to showers and kitchens by calorifiers. Gas boiler for hot water to laundry and changing rooms in summer. Steel flue.
	Temperature Criteria	62°F when outside temperature is 32°F.		
	Air changes	3 per hour.		
	'U' value of walls	0·17		
	'U' value of roofs.	0·16		

Element	Cost/sq. ft floor area s. d.	Specification
26. Ventilation	1·86	Asbestos roof vents No. 15 Mechanical vents to kitchens No. 3 Wall vents to rooms No. 17
27. Drainage (nett cost)	1 5·33	Pipes: main runs 4 in. and 6 in. pitch fibre. branch runs 4 in. stoneware seconds. land drains mainly 3 in. agricultural. Fittings: Salt glazed stoneware. Manholes: Concrete tube 30 in diameter.
28. External works (nett cost)	2 7·57	Tennis courts. Oil storage tank supports, enclosure and fuel mains. Thresholds. Excavations and filling around necessary to site the building.
Total of items 1–28	71 1·45	

APPENDIX 4

LIST OF TREES AND SHRUBS

TREES (at an average supply cost of approx. 15/– each)

Number		Number	
1	Apple (a) Bramley seedling	7	Norway maple
2	(b) Cox's orange pippin	8	Snowy mespilus
1	(c) Worcester pearmain	4	Common oak
4	Acacia	2	Scarlet oak
10	Silver birch	3	Evergreen oak
3	Wych elm	8	Austrian pine
1	Gean	2	Strawberry tree
8	Hawthorn	1	Stag-horn sumach
2	Hornbeam	27	Sycamore
2	Larch	3	Tree of Heaven
7	Red-twigged lime	3	Tulip Tree
2	Maidenhair tree	1	Walnut
2	Maple		

SHRUBS INCLUDING CLIMBERS (at an average supply cost of approx. 5/6 each)

1	Akebia quinata	1	Lonicera japonica halliana
9	Berberis candidula	1	Lonicera japonica aureo-reticulata
3	Berberis verruculosa	2	Lonicera periclymenum
3	Cortaderia argentea	60	Lavandula spica Twickelpurple
1	Clematis armandii	6	Mahonia aquifolium
2	Clematis Nellie moser	22	Mahonia japonica bealii
1	Clematis montana	6	Olearia haastii
30	Cotoneaster horizontalis	10	Phlomis fruticosa
2	Cotoneaster prostata	4	Potentilla fruticosa Katherine Dykes
3	Cistus lusitanicus decumbens	3	Pyracantha lalandii
18	Euonymus radicans varigate	6	Rosa Mme. Leperriere
6	Fatsia japonica	6	Rosa spinossissima fruthlingsgold
2	Ficus carica	12	Santolina incana
1	Forsythia suspensa fortunei	6	Senecio Greyii
6	Genista hispanica	3	Skimmia fragrans
6	Hedera colchica variegata	3	Skimmia japonica
6	Hedera helix caenwoodiana	6	Veronica elliptica latifolia
32	Hedera helix hibernica	3	Vinca major
45	Hypericun calycinum	72	Vinca minor
12	Hysoppus aristatus	6	Vinca major aureo-variegata
1	Jasminum nudiflorum	6	Viburnum fragrans nanum
6	Juniperus sabina pfitzeriana	1	Vitis quinquefolia

HEDGE PLANTS (at an average supply cost of approx. 2/6 each)

55	Cotoneaster simonsii	12	Mahonia aquifolium
10	Berberis stenophylla	48	Myrobalan
72	Hornbeam		

HERBACEOUS PLANTS (at an average supply cost of approx. 2/8 each)

24	Acanthus mollis	40	Hosta glauca
12	Anemone japonica alba	12	Heuchera sanguinea (pluie de feu)
6	Arenaria grandiflora	36	Iris germanica aline
6	Artemisia abrotanum	12	Iris germanica moonbeam
12	Aruncus Sylvester	9	Iris stylosa

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Number		Number	
36	Alyssum saxatile citrinum	6	Lychnis Chalcedonica
24	Ajuga reptans	18	Lysimachia numularia
42	Bergenia cordifolia	1	Macleaya cordata
3	Buptalmium speciosum	24	Mentha requienii
6	Centranthus ruber	18	Onoethera missouriensis
42	Convallaria majallis	12	Paeonia Duchesse de Nemours
60	Epimedium rubrum	8	Polygala calcarea
18	Geranium pratense	6	Primula auricula
21	Geranium sanguineum lancastriense	12	Primula involucrata
12	Gentiana sino-ornata	24	Pulmonaria saccharata
30	Hemerocallis flava	12	Saxifraga umbrosa
6	Helleborus niger	12	Sedum spurium roseum
18	Helxine soleiroleii	18	Thymus serpyllum
27	Heracleum mantegazzianum		

FERNS (at an average supply cost of approx. 6/- each)

7	Dryopteris filix mas	2	Osmunda regallis

WATER PLANTS (at an average supply cost of approx. 5/- each)

2	Nymphaea odorata alba	3	Callitriche verna
6	Scirpus zebrinus		

BULBS (at an average supply cost of approx. 38/- per 100)

400	Crocus aureus	300	Narcissus pseudo-narcissus
300	Crocus nudiflorum	200	Tulipa sylvestris
50	Eranthis Hyemalis		

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Printed and published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
49 High Holborn, London W.C.1
423 Oxford Street, London W.1
13A Castle Street, Edinburgh 2
Brazennose Street, Manchester 2
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Printed in England

S.O. Code No. 27-291-17-65.